RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOLUME XLIII.

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BERLIN: MESSRS. FRIEDLÄNDER UND SOHN.

1913

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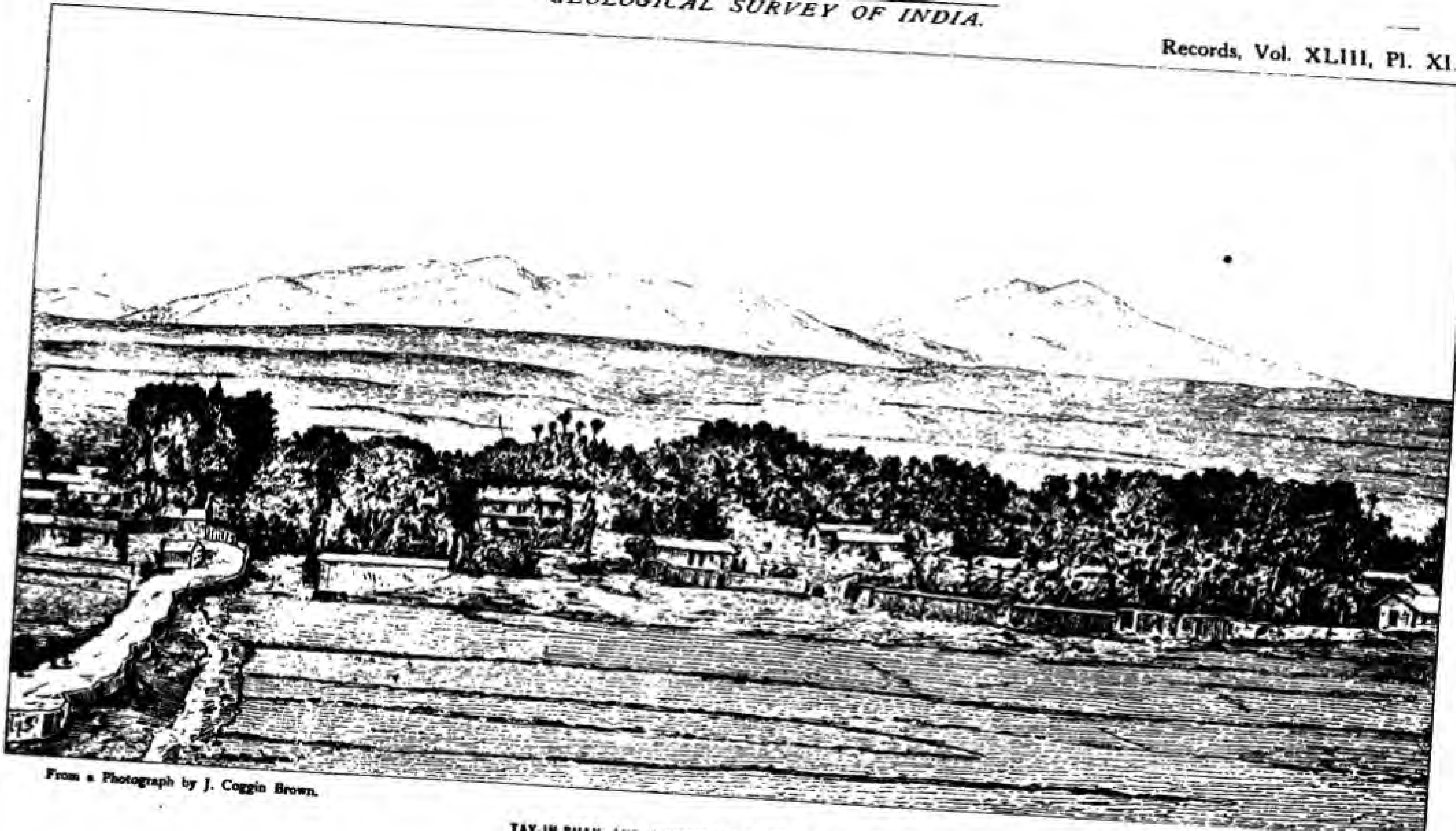
G. S. I. Calcutta.



From a Photograph by J. Coggin Brown.

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G. S. I. Calcutta

Photo by J. Coggin Brown. G. S. I. Calcutta.

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LATE TERTIARY TERRACES NAN-TIEN PLAIN.

Photo by J. Coggin Brown *G. S. I. Calcutta.*

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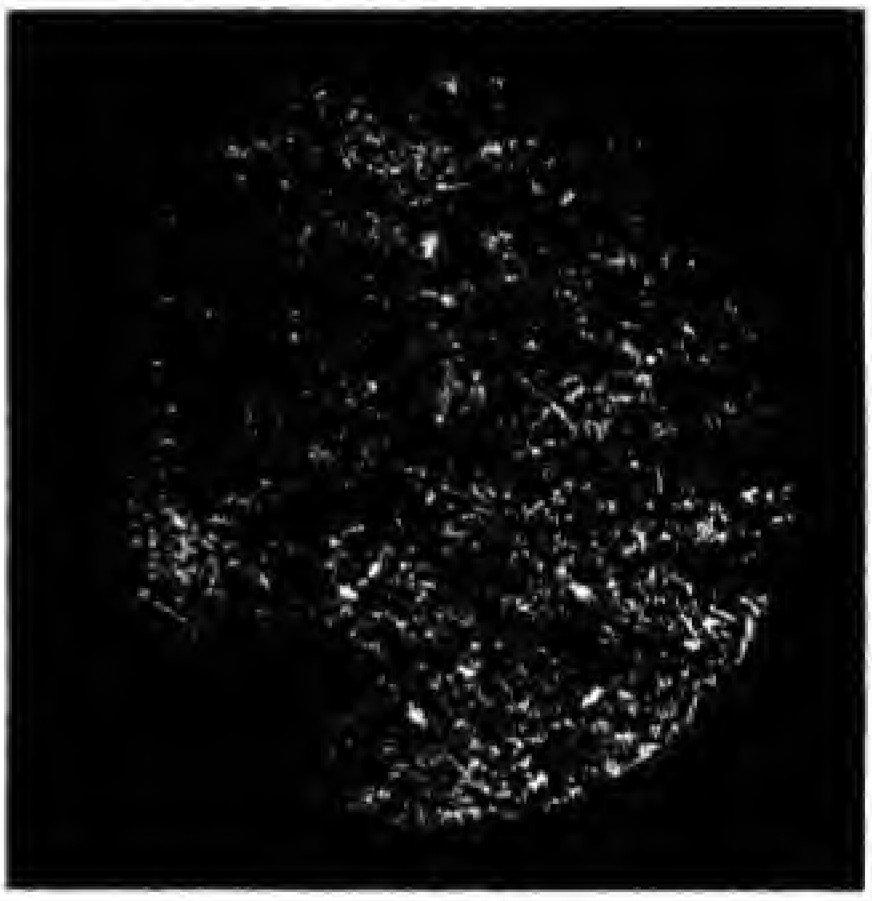

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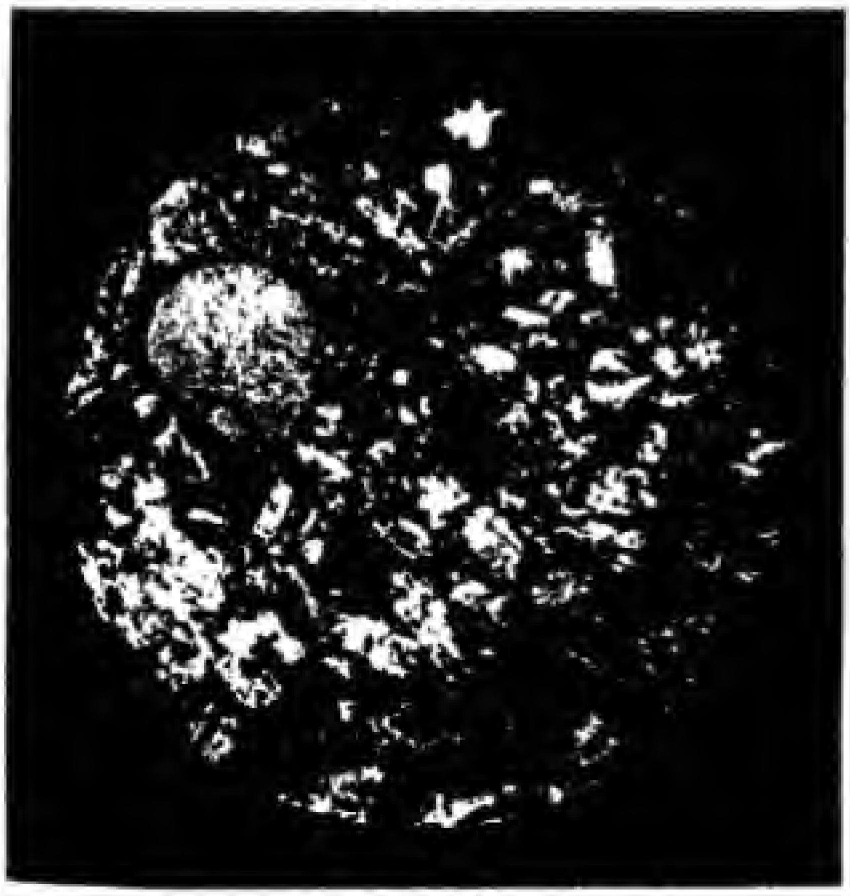

× 19

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Photo. by R. C. Burton.

G. S. I. Calcutta.

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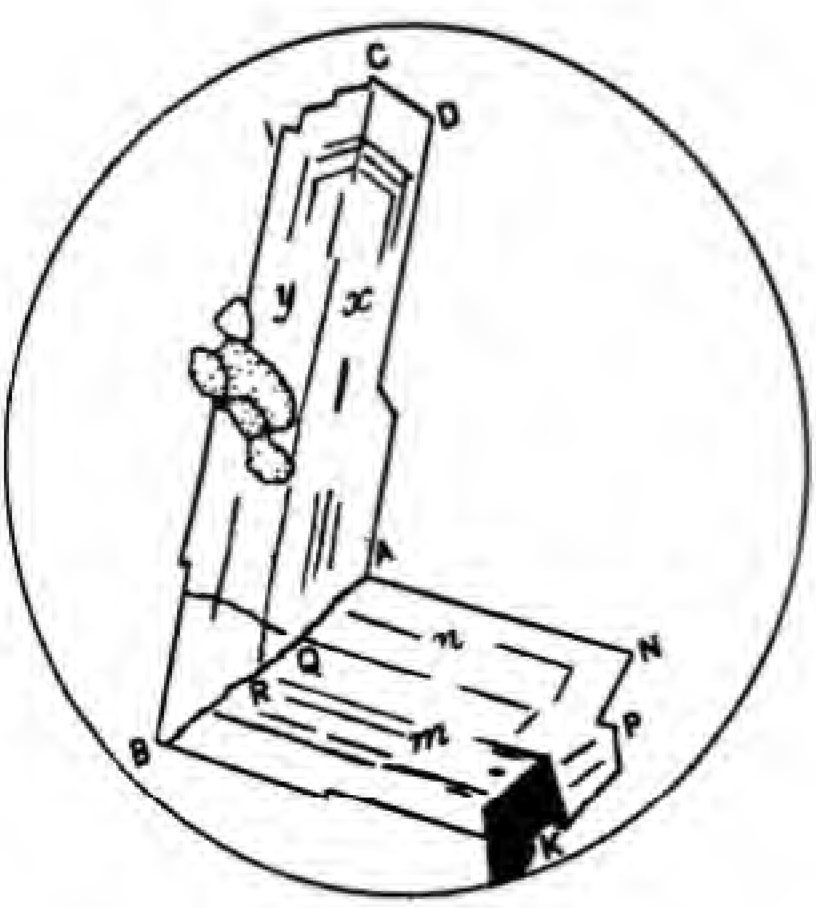

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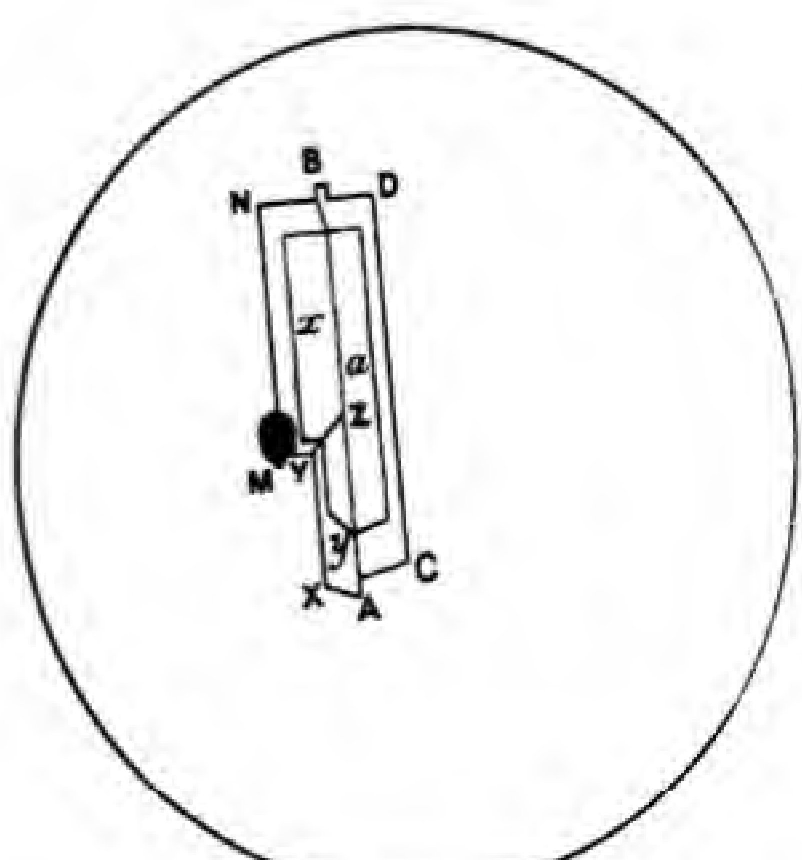

Drawings by R. C. Burton.

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Photo. by R. C. Burton.

G. S. I. Calcutta.

Fig. 1.

× 19

Fig. 2.

× 32

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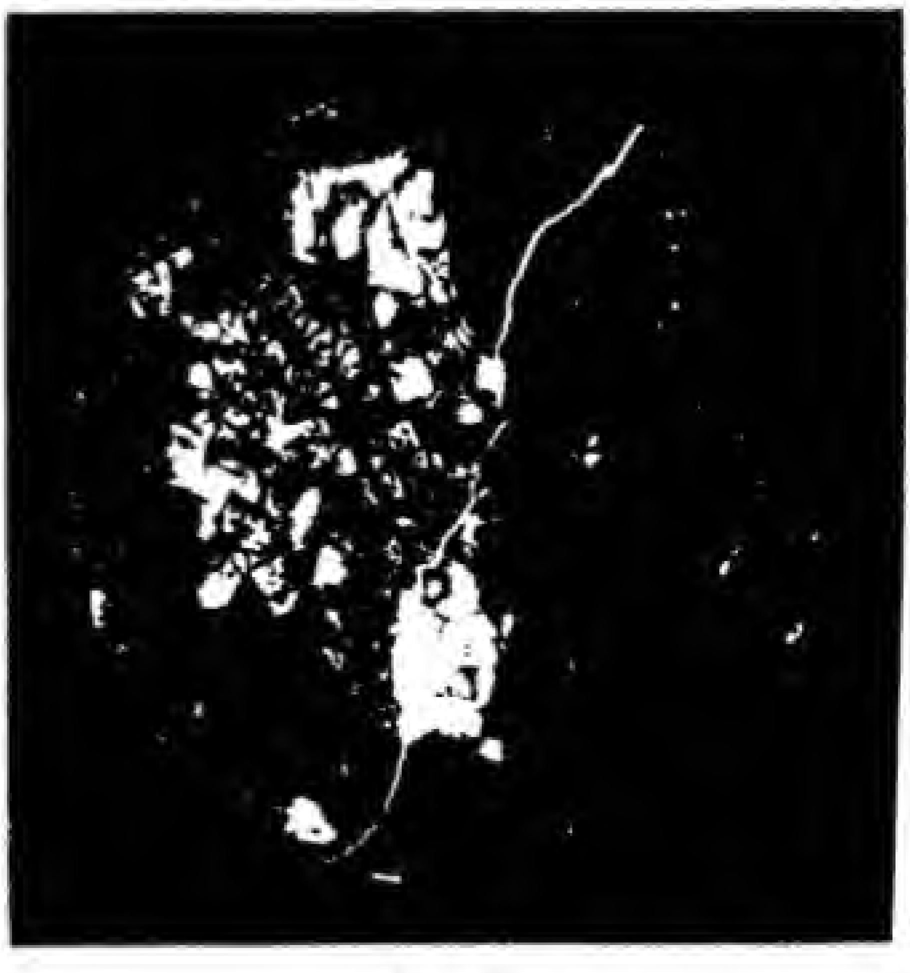
Fig. 4.



× 32

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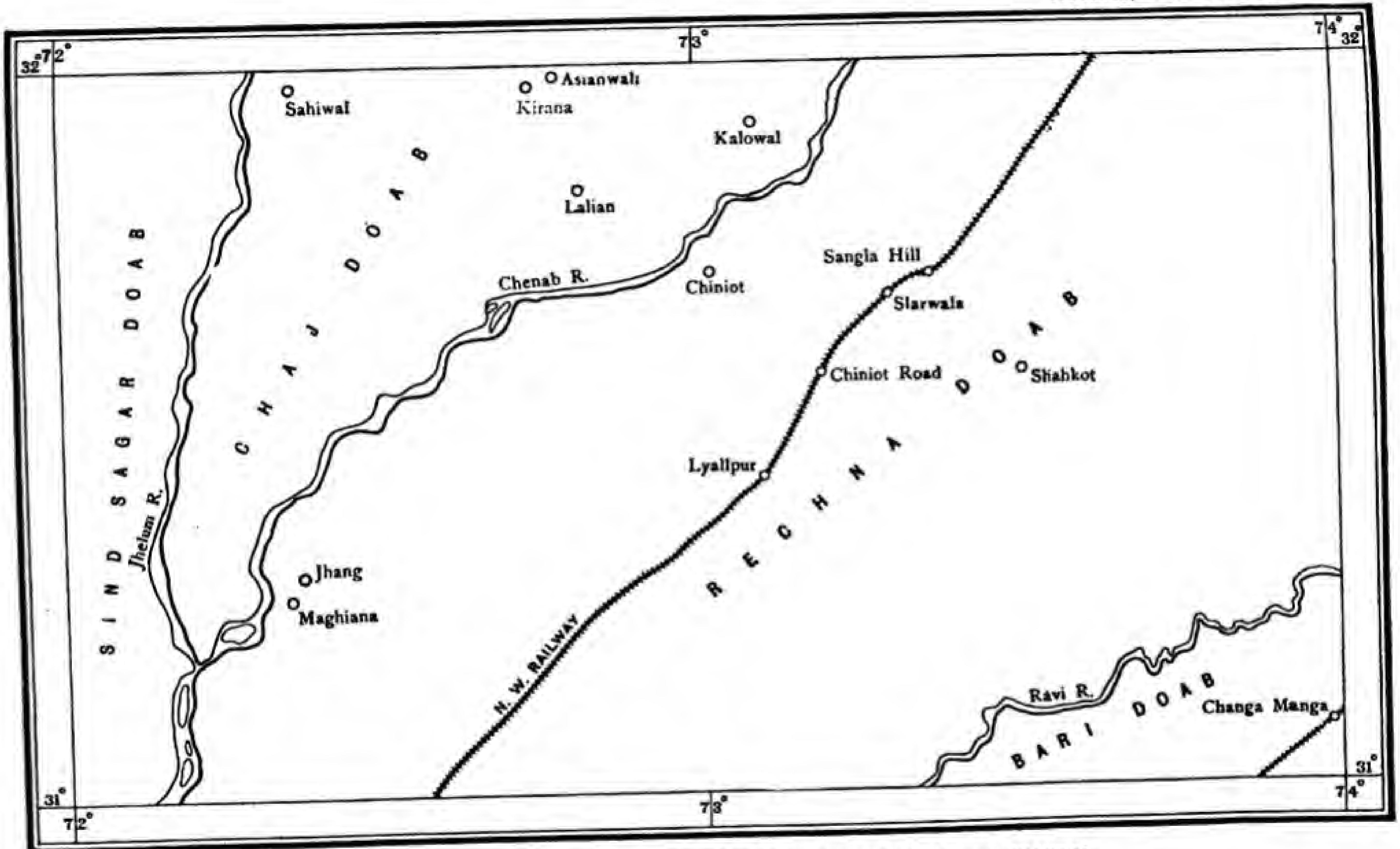

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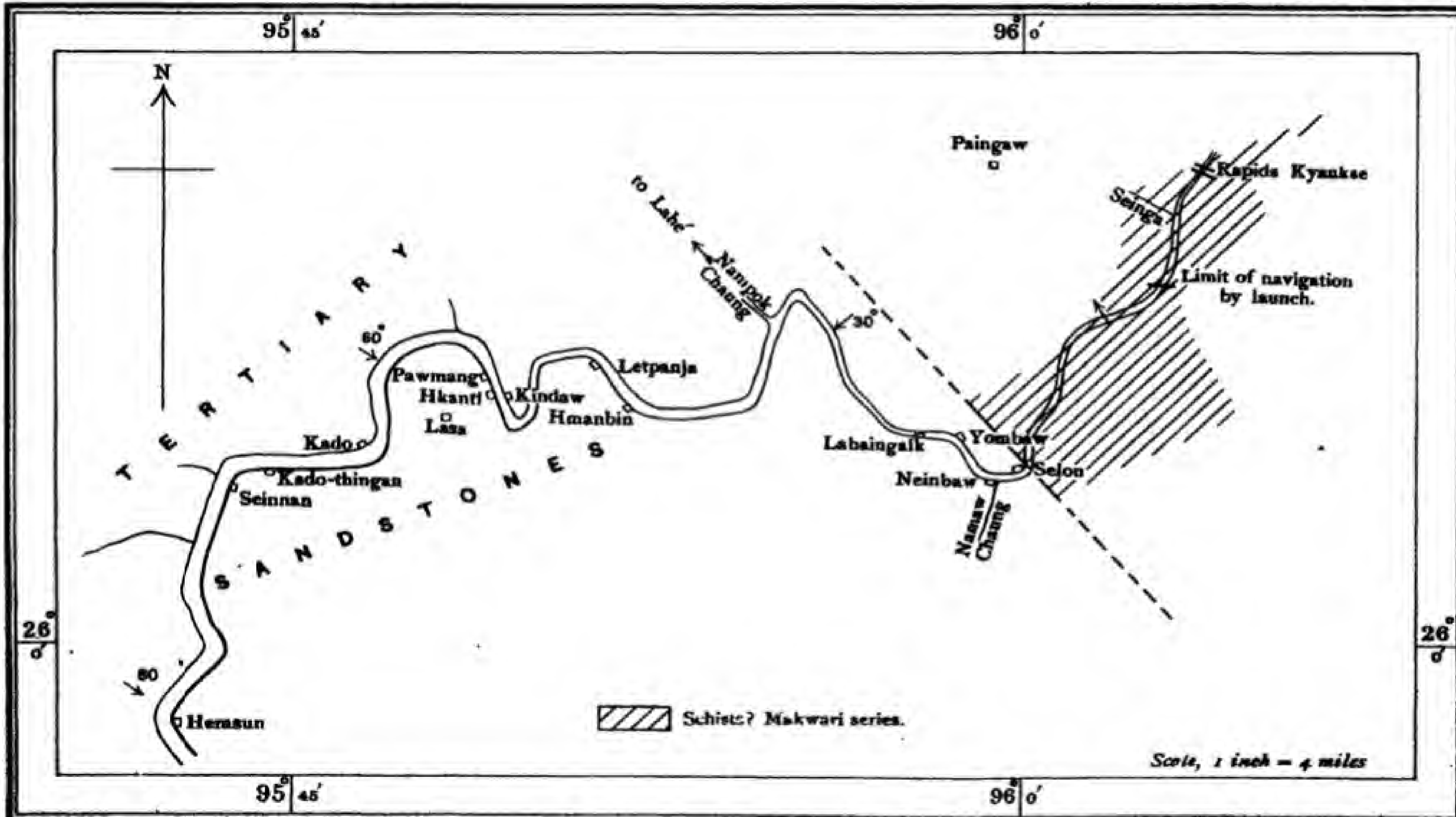
SKETCH MAP SHOWING POSITION of KIRANA, CHINIOT, SANGLA and SHAHKOT.

Scale, 1 inch = 16 miles.



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SKETCH MAP OF PART OF CHINDWIN RIVER.

G. S. I. Calcutta.

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1

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T A Brock del

West, Newman collo

CAMAROCRINUS ASIATICUS, Reed

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

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THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1913. [May.

GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1912. BY H. H. HAYDEN, C.I.E., *Director.*

CONTENTS.

DISPOSITION LIST.

1. During the period under report the officers of the Department were employed as follows :—

Superintendents.

MR. C. S. MIDDLEMISS .	Returned to headquarters on the 13th April 1912. Proceeded to Kashmir on the 1st of June 1912 to continue the geological mapping of the Trias and Carboniferous rocks of the Pir Panjal and the country to the north and east of the Srinagar valley. Returned to headquarters on the 15th November 1912. Placed in charge of the Bombay, Central India and Rajputana party.
MR. E. VREDENBU .	Returned from leave on the 3rd November 1912. Placed in charge of the Burma party and left for the field on the 8th December 1912.
DR. L. L. FERMOR .	Returned to headquarters from the field on the 14th March 1912. Proceeded to Bombay on the 20th March 1912 to report on the occurrences of Iron-ore in Ratnagiri and Goa, and on the 22nd April 1912 to Darjeeling for a survey of the hill-slopes. At headquarters in charge of office from 31st May to 28th October 1912. Placed in charge of the Central Provinces party and left for the field on the 29th October 1912.

Assistant Superintendents.

MR. P. N. DATTA . . Returned from the field on the 2nd May 1912. Granted privilege leave for six weeks with effect from the 4th November 1912. Returned from leave on the 16th December 1912. Posted to the Burma party.

DR. G. E. PILGRIM . Returned from leave on the 16th February 1912 and proceeded to examine the Siwalik rocks in the Punjab. Returned to headquarters on the 22nd May 1912. Appointed Palæontologist from the 1st June 1912. Placed in charge of office with effect from the 23rd November 1912.

MR. G. H. TIPPER . At headquarters as Palæontologist until 31st May 1912. Granted privilege leave for three months combined with furlough for three months with effect from the 14th June 1912, and returned from leave on the 8th November 1912. Deputed to accompany the Karachi Extension Railway Survey Party.

MR. H. WALKER . . Returned to headquarters on the 17th May 1912. Re-posted to the Central Provinces party and left for the field on the 8th November 1912.

MR. E. H. PASCOE . Returned from leave on the 23rd February 1912. Deputed to investigate petroliferous localities in Assam from 1st May to 15th May 1912. Deputed on the 10th October 1912 to examine the oil-bearing regions of the Punjab, North-West Frontier Province and Baluchistan.

MR. K. A. K. HALLOWES. Returned from the field on the 9th May 1912. Granted privilege leave for three months combined with study leave for nine months with effect from the afternoon of the 1st August 1912.

MR. G. DE P. COTTER . Returned to headquarters from the field on the 23rd May 1912. Acted as Curator from 1st June to 4th November 1912. Posted to the Burma party and left for the field on the 5th November 1912.

MR. J. COGGIN BROWN . Returned to headquarters on the 3rd April 1912. Acted as Geological Officer, Oilfields Advisory Board, Yenangyaung, from 12th May to 1st August 1912. Appointed Curator, Geological Museum and Laboratory, with effect from the 5th November 1912.

MR. J. J. A. PAGE . Returned to headquarters on 4th July 1912. Re-posted to Burma in continuation of his previous work in connection with wolfram and tin in Tavoy and Mergui and left for the field on the 27th October 1912.

MR. H. C. JONES . . Returned to headquarters on the 24th May 1912. Deputed to inspect the foundations of a dam at Itarsi from 18th to 26th June 1912. Re-posted to the Bombay, Central India and Rajputana party and left for the field on the 28th October 1912.

MR. A. M. HERON .	Returned to headquarters on the 16th May 1912. Deputed to be Geological Officer, Oilfields Advisory Board, Yenangyaung, from 14th July to 3rd October 1912. Re-posted to the Bombay, Central India and Rajputana party and left for the field on the 20th October 1912.
MR. M. STUART . .	Services temporarily transferred (from the 18th February 1911) to the Madras Educational Department to act as Professor of Geology at the Presidency College, Madras.
MR. N. D. DARU . .	Returned to headquarters on the 8th May 1912. Granted privilege leave for one month with effect from the 13th May 1912. Returned from leave on the 3rd June 1912. Deputed to the College of Science, Poona, as Lecturer on Geology from the 5th June to 25th September. Re-posted to the Bombay, Central India and Rajputana party and left for the field on the 2nd November 1912.
MR. H. S. BION . .	Acted as Curator, Geological Museum, till 31st May 1912. Accompanied Mr. Middlemiss for field-work in Kashmir on the 1st June 1912. Returned to headquarters on the 20th October 1912. Posted to the Burma party and left for the field on the 5th November 1912.
MR. C. S. FOX . .	Returned to headquarters on the 17th April 1912. Re-posted to the Central Provinces party and left for the field on the 19th October 1912.

MR. R. C. BURTON . Joined the Department on the 28th January 1912. Attached to the Central Provinces party and left for the field on the 18th October 1912.

Chemist.

DR. W. A. K. CHRISTIE. Deputed to the Salt Range, from 15th January to 16th March 1912, in connection with an investigation into the quality and value of the potash salts in the Khewra Mines.

Sub-Assistants.

S. SETHU RAMA RAU . Returned to headquarters on the 12th May 1912. Granted privilege leave for one month and thirteen days with effect from the 2nd September 1912. Returned from leave on the 15th October 1912. Attached to the Burma party and left for the field on the 8th November 1912.

MR. VINAYAK RAO . Returned to headquarters on the 1st May 1912. Granted privilege leave for three months with effect from the 2nd May 1912. Returned from leave on the 2nd August 1912. Attached to the Central Provinces party and left for the field on the 30th October 1912.

Assistant Curator.

MR. A. K. BANERJI . Appointed on the 21st May 1912. At headquarters for the rest of the period under report.

ADMINISTRATIVE CHANGES.

Appointments. 2. MR. R. C. BURTON, B.Sc., F.G.S., joined the Department on the 28th January 1912.

3. MR. H. S. BION acted as Curator till 31st May 1912.

MR. G. DE P. COTTER was appointed to act as Curator from the 1st June to 4th November 1912, *vice* Mr. Bion.

MR. J. C. BROWN was appointed to act as Curator from the 5th November 1912, *vice* Mr. Cotter.

DR. G. E. PILGRIM was appointed Palæontologist with effect from the 1st June 1912, *vice* Mr. Tipper on leave.

MR. A. K. BANERJI was appointed Assistant Curator with effect from the 21st May 1912.

Promotion. 4. MR. P. N. DATTA, Assistant Superintendent, was appointed to officiate as Superintendent, *vice* Mr. G. H. Tipper on leave from the 14th June 1912, and *vice* Mr. E. Vredenburg on leave from the 14th September 1912.

Leave. 5. MR. P. N. DATTA was granted privilege leave for six weeks with effect from the 4th November 1912.

MR. G. H. TIPPER was granted privilege leave for three months combined with furlough for three months with effect from the 14th June 1912.

MR. K. A. K. HALLOWES was granted privilege leave for three months combined with study leave for nine months with effect from the 2nd August 1912.

MR. N. D. DARU was granted privilege leave for one month with effect from the 13th May 1912.

OBITUARY.

6. I regret to have to record the death in Calcutta on December 29th of Mr. Robert Bruce Foote, formerly senior Superintendent in this Department. Mr. Foote joined the Geological Survey in 1858 at the age of 24 and retired in 1891 after a service of a little over 33 years. The greater part of his service was spent in Southern India, where almost the whole of the Madras Presidency and the south-western portion of the Bombay Presidency

were surveyed and described by him and his colleague, the late Dr. King: a joint record unsurpassed by that of any two other members of the Geological Survey.

7. Strictly comparable to the great area covered by his work was the wide range over which it extended; for it embraced not only the geology of the crystalline rocks, which form such a large proportion of the Peninsula, but also stratigraphical and palæontological researches and extensive studies of the character and distribution of the prehistoric stone implements of India. Along each of these lines Mr. Foote made his mark; he was the first to separate definitely the Dharwar system from the South Indian crystalline complex and his papers on "The Dharwar system, the chief auriferous rock series of South India" marked an important advance in, and still remains the basis of, the subdivision and classification of the Archæan group of the Peninsula.

8. In the field of palæontology Mr. Foote made a valuable addition to our knowledge of the pleistocene founa of India by his discovery and description of a new species of rhinoceros, named by him *R. deccanensis*, which he found in the cotton soil of Belgaum.

9. His numerous papers, both critical and descriptive, published in the *Records* and *Memoirs* of the Geological Survey testify to Mr. Foote's great scientific activity.

10. On his retirement Mr. Bruce Foote spent three years in Baroda and subsequently published a monograph descriptive of the geology and mineral resources of that State. Since then most of his time had been spent at Yercaud in the Shevaroy Hills, whence he had kept closely in touch with the members of his old department, by all of whom his loss will be most deeply regretted.

PUBLICATIONS.

11. The publications issued during the year under review comprise one volume of *Records*, one of *Memoirs* and four memoirs of *Palæontologia Indica.*

LIBRARY.

12. The additions to the library during the year 1912, amounted to 3,337 volumes, of which 1,166 were acquired by purchase and 2,171 by presentation and exchange.

MUSEUM AND LABORATORY.

Staff.

13. Mr. H. S. Bion was Curator of the Museum and Laboratory until the end of May, after which Mr. G. de P. Cotter was appointed. The latter continued to act till the 4th November when Mr. J. Coggin Brown took over charge. Mr. Ajit Kumar Banerji, B.A., was appointed Assistant Curator with effect from the 21st May. Babu Durga Sankar Bhattacherji and M. R. Ry. A. S. Subba Iyer, Museum Assistants, were confirmed in their appointments.

Determinative and chemical work.

14. The number of specimens referred to the Curator for examination and report was 352; of these, assays and analyses were made of 47. Dr. W. A. K. Christie has been engaged chiefly in the investigation of the potassium salt deposits of the Punjab Salt Range (see p. 20). Besides the miscellaneous work of the laboratory he has carried out a number of complete analyses of igneous and metamorphic rocks, including a series of rocks from Idar State collected by Mr. C. S. Middlemiss.

Donations to Museums, Educational Institutions, etc.

15. Until the present year it had been impossible to comply with all of the very numerous requests made by Museums and educational institutions in India for collections of typical specimens, but the recent addition to the staff of two posts of Field Collector, has resulted in the acquisition of material suitable for distribution. During the year collections of Indian specimens were presented to the following institutions :—

(1) The Government Commercial Classes, Calcutta;
(2) The London Missionary Society's Institution, Calcutta;
(3) The Durgapur High English School, Chittagong;
(4) Shrewsbury School;
(5) The Presidency College, Calcutta;
(6) The Prince of Wales College, Jammu;
(7) The Presidency College, Madras;
(8) The College of Engineering, Poona;
(9) St. Mary's Convent High School, Naini Tal;
(10) The Victoria Technical Institute, Nagpur.

A set of specimens illustrating the Gondite series was presented for purposes of study to Professor Grubenmann of Zurich. A collection of specimens of Indian maganese ores was also sent to Dr. Richard Beck, Geologisches Institut der Kgl. Bergakademie, Freiberg, in exchange for specimens of moldavites.

16. The following are among the specimens acquired by donation during the year :—

Donations received.

(1) Kyanite with blue corundum, from Ranchi; presented by Mr. H. M. Fox.

(2) Hornblende asbestos from Seraikela, Singhbhum district; presented by the Rajah Bahadur of Seraikela State.

(3) Iron pyrites from Sain Bel, Rhône, France; presented by Mr. A. Shrager.

(4) Wolframite from Dolcoath mine, Camborne, Cornwall: presented by Mr. A. Shrager.

(5) Lead, containing 4 oz. per ton of silver, from the Nam Tamai, tributary of the Upper Irrawaddy; presented by Captain B. E. A. Pritchard, I.A.

(6) Blödite, from the Mayo Salt Mines, Khewra; presented by Messrs. Lyon and Reid of the Northern India Salt Revenue Department.

Fossil Invertebrate gallery.

17. The re-arrangement of the Invertebrate Fossil gallery is proceeding. Show cases have been arranged to illustrate the following additional fossil series, the Jurassic of Spiti, the Himalayan Trias, the Himalayan Devonian, and the Lower Tertiary of Burma. All the specimens contained in these cases have been provided with printed labels.

Siwalik gallery.

18. Three additional show cases have been placed in the Siwalik gallery to accommodate the new types added to the collection by recent work in the Salt Range and Baluchistan. A fine series of North American Tertiary mammalia has been presented to the Geological Survey by the American Museum of Natural History.

19. Several models of Indian Tertiary Vertebrate types have lately been prepared, and it is intended to continue this work so that it may be possible to distribute them to other Museums. Repairs and renovations to existing models both of Indian and foreign vertebrates have also been executed.

Collection of duplicates of typical rocks.

20. Babu Bankim Bihari Gupta, Field Collector, was employed during the season (1) in making collections of the several varieties of granites and gneisses in the Nakta nala, (2) in collecting representatives of the various Deccan Trap flows in the Linga area, (3) in collecting specimens of hollandite, sitaparite, braunite and fermorite, from the Sitapur manganese mine, and (4) in collecting duplicate series of the rocks described in Dr. Fermor's paper on the petrology of the Sausar Tahsil (*Records*, *G. S. I.*, Vol. XXXIII, part 3).

MINERALOGY AND PETROLOGY.

White pyroxene rock: tremolite: bowenite.

21. Mr. Middlemiss has described some interesting mineral occurrences from the Aravallis of Idar State. At Bamanvada (lat. 23° 36′, long. 73° 20′) massive, white pyroxene rock is found associated with crystalline limestone and quartz-pyroxene schist, the whole series being intercalated as a band, 50 to 60 feet thick among mica schists. The coarsely crystalline, often pure white, pyroxene is found in beds of from a few feet to as much as 30 feet thick at one place, and may be traced at intervals for many miles. Although pyroxene as a constituent of many igneous rocks is common, this is the first instance recorded of extensive beds of the pure mineral having been found in India. Its optical and chemical characteristics are those of the diopside group of monoclinic pyroxenes, and it suffers local changes into white or pale green tremolite or actinolite in radiating tufts and interlaced fibres. Some of the latter layers are rather compact and semi-translucent, but not sufficiently so to have any value as jade (nephrite) as at present explored, though the occurrence is suggestive. The white pyroxene rock mottled here and there by the pale green tremolite makes a tough and handsome ornamental stone when polished.

22. At Bhetali, seven miles along the outcrop from Bamanvada, a grey mottled variety appears with graphite in nests and films round and among the pyroxene crystals. Some of the associated crystalline limestone at Bamanvada shows small patches of hard dark green serpentine (bowenite) resembling in a small way that from the Safed Koh described by McMahon (*Min. Mag.*, Vol. IX, p. 187, 1890). Mr. Middlemiss concludes from the lie and associations of this band of rocks that they are mainly the result of

contact-metamorphism induced by dykes of olivine-gabbro and dolerite which penetrate the series.

Idocrase.

23. Mr. Middlemiss has further recorded massive idocrase (vesuvianite) from near Nadri (lat. 24° 0′, long. 73° 2′). This mineral does not seem to have been much more than mentioned before in India, with the exception of that from Tonk referred to by Mallet (*Man. Geol. of India*, pt. 4, *Mineralogy*, p. 93). Mr. Vredenburg doubtfully recognised it in some Idar granite collected by Professor Page, a point which so far Mr. Middlemiss has not been able to verify. The present occurrence is in metamorphic Aravalli limestones, which in the neighbourhood are modified by intrusive veins of granite and aplite into a rock composed of calcite, quartz, microcline, diopside, wollastonite, etc., and secondly into the rock now described, by further intrusion into them of the later bosses of Idar granite. The rock is coarsely crystalline, with large shining cleavage plates of poikilitically developed idocrase among and including the other normal constituents of the calc-gneiss. The bands are several inches across, the proportion of the mineral to the rest of the rock being about 5 to 1. The determination is based on physical and optical tests, no chemical examination having yet been made.

Teng-yueh volcanics.

24. Mr. R. C. Burton has examined and described a series of volcanic rocks collected by Mr. Coggin Brown in the neighbourhood of Teng-yueh. These consist of three groups :—

(*a*) pyroxene-andesites ;
(*b*) hornblende-andesites, pyroxene-andesites, with augite-olivine andesites and olivine basalt ;
(*c*) olivine basalts.

These sub-divisions correspond with the three groups respectively termed by Mr. Brown "bedded andesites," "massive andesites" and "basalt lavas of Tay-in-shan," and are enumerated in order of age, the first being the oldest. The rocks of group (*a*) are very much older than those of group (*b*), which are of pliocene and pleistocene age, some of the lavas, as for example those of the now extinct She-toe-shan crater, being of recent age.

25. In general characteristics the andesites and basalts described by Mr. Burton are similar to those of the younger Burmese volcanoes, the lava of Ho-shuen-shan being comparable to the late Tertiary basalts of the Northern Shan States. A specimen of augite

andesite from Kan-lan-ssu contains a considerable amount of brown glass resembling the palagonite of the Rajmahal trap.

A suggested infra-plutonic zone in the earth.

26. An interesting paper read by Dr. Fermor before the Asiatic Society of Bengal (*Journ. A. S. B.*, Vol. VIII, No. 9, p. 315) led him to the consideration of the conditions existing below the surface of the earth, from which he has deduced the presence, below the plutonic zone, of a belt of material under high pressure and containing garnet as a typical constituent; this he terms the infra-plutonic zone, with which he deals in a preliminary note published in this part of the *Records*. Although admittedly of a somewhat speculative nature, the views put forward by Dr. Fermor are of great interest and highly suggestive; his memoir on the subject when published will undoubtedly form a very important contribution to the study of the chemical and physical constitution of the earth.

PALÆONTOLOGY.

Tertiary mammals in the British Museum.

27. During his absence on study leave Dr. Pilgrim examined most of the types of mammalia now in the British Museum from the Upper Siwaliks of the Siwalik Hills, as also from Perim Island and Burma. These have been described partly by Falconer and partly by Lydekker, and there are very few duplicates in the Geological Museum in Calcutta. Dr. Pilgrim also examined the fine collection of Pikermi species in the British Museum for purposes of comparison with our Middle Siwalik fauna. At the same time he worked out and described a small collection of *Carnivora* from the Lower Siwaliks of Chinji and also from the Middle Siwaliks. This work will, it is hoped, serve as a nucleus for a more extensive revision of the Siwalik *Carnivora* to be undertaken subsequently. Another group examined by Dr. Pilgrim was the *Mastodontidæ*, which he found to be also in need of revision.

28. Mr. Swinhoe's collection of mammals, which is in the British Museum, was also examined. The specimens are from two localities, namely (1) the right bank of the Irrawadi opposite Mandalay and (2) near Yenangyaung. The collection from the former locality was found to include *Elephas antiquus* (*namadicus*) and is therefore presumably of pleistocene age. Among the specimens from near Yenangyaung Dr. Pilgrim found a new species of

Merycopotamus, of which, with Dr. Smith Woodward's consent, he has written a description. Other interesting specimens noticed were a skull from Perim Island attributed by Lydekker to the genus *Strepsiceros*. Dr. Pilgrim on developing this specimen to a considerably greater extent than had formerly been done, found the generic attribution no longer tenable and regards the skull as representing a new genus.

29. Another interesting skull which had apparently been overlooked for some years bears a label containing the word "Ava." If the specimen really came from Ava its age is presumably Middle Siwalik, since numerous Middle Siwalik species have been obtained from that locality. If this is so, its presence is interesting, since Dr. Pilgrim regards it as undoubtedly an ancestral form of the Pliocene *Leptobos*. He also found that it possessed decided antelopine affinities. In view of the interest attaching to it Dr. Pilgrim wrote a description of the specimen with Dr. Smith Woodward's permission.

30. A fine collection of *Hipparion* skulls from Pikermi also proved of considerable interest, being found to comprise two species, namely, the pontian form *H. gracile* and also another which Dr. Pilgrim regards as almost, if not quite, identical with the Indian form *H. punjabiense*, from the Middle Siwaliks of the Salt Range.

Tertiary mammals at Basle.

31. Dr. Pilgrim also paid a visit to Basle where Professor Stehlin very kindly allowed him to examine numerous specimens which proved to be interesting and useful for purposes of comparison with Siwalik forms.

Tertiary Mollusca of Sind and Baluchistan.

32. Mr. Vredenburg was also absent on study leave during the year and examined collections of Tertiary invertebrate fossils both in England and on the Continent, for purposes of comparison with the Tertiary fossils of Sind and Baluchistan, on a description of which he has been engaged for some years past. His work comprises two main sections, firstly, the revision of the Sind Tertiary types of D'Archiac and Haime and secondly, a complete description of the post-eocene Tertiary molluscan fauna of North-Western India. D'Archiac and Haime's types have been carefully revised and their geological horizons ascertained. Most of the mollusca proved to be from the Gaj and Laki stages, the

Gaj being chiefly represented and the fossils from it as a rule well preserved, whereas the specimens from the Laki stage were usually casts. There are also a few Ranikot forms, very few from the Nari, none from the Khirthar, and only one from the Cretaceous. The post-eocene mollusca that have been described by Mr. Vredenburg comprise over 350 species of which about 120 are new. Mr. Vredenburg finds that the only forms that show any close relationship to European species are those from the Nari, whereas the percentage becomes very small in the Gaj beds and still smaller, practically none, in the Hinglaj, the fossils of which latter stage are closely related to those of Java.

Jurassic ammonites.

33. Before taking leave Mr. Tipper was engaged on the description of the Jurassic fossils from Baluchistan on which he has been engaged for some years. He has made considerable progress in the work and it is hoped that his results will soon be ready for publication.

Palæontological work being done in Europe.

34. The Cretaceous fossils collected by me at Kampa dzong and Tuna in Tibet and the Jurassic brachiopods collected by Messrs. La Touche and Datta in the Shan States are still in the hands of Professor Douvillé and Mr. S. S. Buckman respectively.

35. The collections of Palæozoic fossils made by Mr. Griesbach in N. W. Afghanistan and Khorasan and by me in the Koh-i-Baba have been examined and described by Miss Colley March, B.Sc., of Manchester University. Mr. Griesbach's collections contain well-preserved brachiopods, the best having been obtained from Robat-i-pai near Herat; they include species of *Spirifer* (cf. *bisulcatus* and cf. *clathratus*), *Productus* (*semireticulatus* and *pustulosus*), *Camarophoria* cf. *purdoni* and *Atrypa aspera*. Miss March regards these fossils as essentially Lower Carboniferous, and ascribes the presence of *Atrypa aspera* to a local survival of this species beyond the usual Devonian limit; experience of the difficulties under which specimens are collected during expeditions of the kind on which Mr. Griesbach was engaged at the time, would dispose me rather to infer that he had not had an opportunity of working out horizons in detail and consequently did not suspect the presence of more than one system; it is clear from his lists that fossils collected from beds some little vertical distance apart were not differentiated, and the collection might thus easily contain both Lower Carboniferous and Upper Devonian species. The close

association of fossils belonging to these two systems near the Kotal-i-Hajigak in the Koh-i-Baba lends considerable colour to this explanation.

36. Miss March has also described the fossils collected by me from the upper beds of the Hajigak limestone; they are badly preserved, but were found to include *Spirifer wynnei*, *Chonetes* cf. *hardrensis*, (?) *Phillipsia derbiensis*, a new species of *Streblodus* named by Miss March *Str. incurvus*, and several species of *Zaphrentis* and *Syringopora*. The most striking feature of all these fossils is, according to Miss March, their close affinity to European forms. Their age is regarded as Lower Carboniferous.

37. A description of the lamellibranchs of the Ranikot stage by Messrs. Cossmann and Pissarro has been received and will shortly be published.

38. During the year, Professor Seward completed his examination and description of the Gondwana plants collected by Mr. Middlemiss on the Golabgarh pass. These include *Glossopteris indica* Schimp and *Cordaites hislopi* Bunb., both typical species of the Lower Gondwanas of the peninsula; they thus furnish unequivocal evidence of the identity of the Gondwanas of Kashmir with those of the coalfields of India. Prof. Seward's memoir has been published in the *Palæontologia Indica.*

ECONOMIC ENQUIRIES.

Building Stones.

39. The limestone of which the Simla town-hall is built was submitted to the Geological Survey for examination and report. It was said to have been obtained from the quarries on Prospect Hill and was found to be very friable and impure, and not suitable for building purposes. Specimens of the Sanjauli quartzite were also examined and found to be excellent building-stones.

Coal.

Raniganj coal-field.

40. The re-survey of the Raniganj coal-field and revision of the map originally prepared by the late Dr. Blanford, on which Mr. Walker was engaged on behalf of the Mining and Geological Institute, in co-operation with a committee of the members of that body, was completed

during the year. Mr. Walker's report on the correlation of the seams has also been handed over to the Institute by which it will be published.

Coal in Korea State, C. P.

41. Attention having recently been drawn to the possibility of exploiting profitably the coal-fields in the Korea State of the Central Provinces originally examined by Mr. Hughes (*Memoirs, Geol. Surv. India*, XXI, pt. 3), the Chief Commissioner has asked that a member of the Geological Survey should make a more detailed examination of the area. The matter has therefore been taken up by the Central Provinces party and Dr. L. L. Fermor proceeded to Korea at the end of the year. Having only just arrived on the field at the conclusion of the period covered by this report, his results are not yet available. Samples of coal, however, were sent for assay to this Department in September 1912, by the Political Agent, Chhatisgarh Feudatory States; these proved to be of fair quality, the percentage of ash being about 6; the percentage of moisture is undesirably high and varies from 7 to 10 per cent; the calorific value of the better samples ranged between 6,650 and 6,850. The localities from which the best samples were obtained are Kouraia nala, Kurasia and Kukri nala.

Engineering Questions.

Darjiling landslips.

42. In pursuance of the recommendations of the landslip committee which met in Darjiling in October 1911, Dr. L. L. Fermor was employed during the summer of 1912 in making a detailed geological survey of the Happy Valley and neighbouring hill-sides. Through the courtesy of Lt.-Colonel R. T. Crichton, C.I.E., Director of Surveys, Bengal, he was provided with large contoured maps. Dr. Fermor's more extensive survey has, while greatly amplifying them, tended to confirm the results arrived at by the Committee. His recommendations and conclusions have been forwarded to the Government of Bengal.

Dharmsala hill slopes.

43. The conditions of the hill slopes at Dharmsala having given cause for apprehension lest landslips might occur, a committee was appointed to examine the station and report to the Local Government. The services of a member of the Geological Survey having been asked for in this connection, Mr. C. S. Middlemiss joined the committee

on his way back from field-work in Kashmir at the end of the monsoon season. Having visited Dharmsala in 1905 in the course of his investigation of the effects of the great earthquake of April 4th, his intimate knowledge of the geological conditions rendered Mr. Middlemiss peculiarly suitable for this further investigation. His conclusions, which were submitted with the report of the committee, tend to show that there is no immediate danger to be apprehended so long as certain necessary precautions be taken without delay. These include the afforestation of bare hill-sides and the closing to grazing and wood-cutting of those already partially deforested; in addition to this certain measures are recommended with regard to rendering the water channels and the drainage system more efficient.

Gold.

Burma.

44. Mr. H. S. Bion was deputed at the beginning of the field-season of 1912-13 to take up the examination of the auriferous gravels of the Chindwin river. His work only covers a short period during the year under review, and comprised chiefly an inspection of the gravels at the small gold-washing villages of Manlaikgyi and Manlaikgale, seven miles below Kindat; these were found to be valueless. The gravel island opposite Helaw was also examined and the gold content found to be very irregularly distributed. The surface gravels, which are quite rich in places (carrying from 8 to 15 grains per cubic yard), are barren in others. Only the surface is rich, there being practically no gold at a depth of four feet. Traces of platinum also were met with.

Iron.

Goa and Ratnagiri.

45. In March 1912, Dr. Fermor visited the iron-ore deposits of Goa and Ratnagiri, where the Compagnie des Mines de Fer de Goa and Messrs. Jambon & Co. respectively gave him every facility to inspect their properties. In Goa, the iron-ore occurs in beds of the Dharwar system, and the total amount is believed to be very considerable. In the southern parts of Ratnagiri and in the adjoining State of Savantvadi, similar geological conditions prevail, and deposits of iron-ore have been found, at Redi in Ratnagiri and near Banda in Savantvadi. It is considered probable that before long an export trade may be developed from this part of India.

46. Mr. Heron records the presence of large quantities of hematite in the Raialo marbles near Raialo and Nimla. He attributes these deposits to metasomatic replacement of the calcite by iron-bearing solutions. Whenever a hillock is seen in the Raialo marble, it is found to be due to the superior resistance to denudation of these masses, which stand out as dark-coloured piles of rock from the level stony plain of yellow or pale brown weathered marble. The rock varies, according to the amount of replacement, from marble stained brown by iron, to nearly pure hematite. The deposits are elongated more or less in the direction of the strike, but thicken and thin out in a quite irregular fashion; they are, in fact, lines of irregular lenticular masses rather than bands. It is difficult to estimate their real thickness, as the slopes are covered with boulders which are strewn to a great distance around and quite obscure the rocks beneath, giving an appearance of thickness greater than is really the case. Bands up to seven or eight feet across of pure hematite, were measured, and there are many much wider. If thin calcareous bands, which would be mined along with the ore and eliminated by hand-picking, are included, the width must run to many yards, and the amount of ore is certainly very great. The locality is situated about 15 miles from Dosa railway station, the intervening country presenting no impediment to railway and tramway construction. Extensive old workings are also seen near Nimla and between Raialo and Kalajpuri; these probably supplied part of the raw material for the now extinct iron industry of Bhangarh.

Jaipur State.

Kaolin.

47. Mr. Heron records the presence in Jaipur State of deposits of kaolin which may possibly be of value. 1¼ mile S. E. of Rasnu (26° 41′; 76° 37′) a long and spacious tunnel has been driven along the strike of a bed of kaolin which runs midway in the ridge of Alwar quartzites and is about 20 yards wide, white but rather impure, banded with quartzite. There is evidently a very large quantity available. It has been quarried for local uses only, such as white-washing, etc. Kaolin is also dug from the soft argillaceous and talcose zone near the base of the Alwars at the north end of the Lalso hills, chiefly near Daraoli (26° 55′; 76° 58′). There are two beds

Jaipur State.

separated by quartzite; the upper one provides a white and fairly pure clay, slightly mottled with pale purple and pink.

Petroleum.

Assam.

48. Mr. Pascoe completed his examination of the petroliferous localities of Assam and prepared a memoir which is now in process of publication.

Burma.

49. During the early part of the year, Mr. Cotter was on duty at the Yenangyaung oilfield, where he was succeeded by Mr. Coggin Brown. Owing, however, to his health giving way, the latter officer was relieved in July by Mr. Heron, who remained at Yenangyaung until the beginning of the field-season of 1912-13.

50. Sub-Assistant Sethu Rama Rau describes petroliferous areas at Yeyodaung and 3 miles N. N. W. of Nga-hlain-dwin in Minbu district. At the former locality, where a Burmese well has been dug, the beds at the crest of the anticline dip at low angles of from 10° to 12°. There are also a few Burmese wells at the second locality, and both places are regarded as being probably of economic value. The oil is said to occur in the upper beds of the eocene series.

Punjab and N.-W. F. Province.

51. Having completed his work in Assam, Mr. Pascoe proceeded to examine the petroliferous localities of the Punjab and North-West Frontier Province, and was still engaged on this work when an attack of suspected enteric compelled him to return to hospital at Lahore. His results are not therefore available yet.

Potash Salts.

Salt Range.

52. Dr. W. A. K. Christie was deputed in January to the Salt Range in the Jhelum District of the Punjab to investigate the potash salts found in his previous prospecting operations in the rock-salt mines at Khewra and Nurpur, worked by the Department of Northern India Salt Revenue. The potash beds found in the Mayo Mine at Khewra are generally overlain by seams of unsaleable marl, and their investigation is rendered difficult because the mining authorities, being mainly concerned with the extraction of marketable salt, which exists in unlimited quantities, naturally change the sphere of their operations as soon as a marl seam is struck and before

the deposit underlying it is exposed. The principal potash-bearing bed found in the Pharwala section of the Mayo Mine was traced at various points for some 850 feet along its strike, and over 250 feet with the dip, which is about N. 30° W., with an inclination of 20 to 50°. Its average thickness is six feet and the potash content varies from 6·8 to 9·6% of K_2O. The distances given are indications of the comparatively extensive nature of the deposit, but they are not intended as a basis for calculation of the material available for extraction, as questions of expediency in pillar preservation complicate the issue. Another seam eight feet thick and carrying 7·7 per cent of K_2O was found in a prospecting drift in the Pharwala salt,—what was presumably the same bed being struck in another prospecting drift 700 feet to the E. N. E. In the Buggy section of the Mayo Mine the only seam of any importance that was found was traced for about 150 feet along its strike, which is E. N. E.—W. S. W. The dip of the bed is about 35°, its average thickness two feet nine inches, and it carries 14·4 per cent of K_2O. The seam thins out when followed upwards along the bedding; in another chamber, at a distance of 170 feet south from the nearest exposure, it was found to be only a few inches thick. The seam in the Nurpur mine is exposed only in one place which is difficult of access. It dips S. S. E. at about 75° and at this point is six feet thick. A typical specimen from this deposit carried 14·1 per cent of K_2O.

53. The potassium-bearing minerals of the salt formation are chiefly langbeinite and sylvin, kainite and blödite with a small percentage of potassium being often present in small quantities. The deposits are usually fine-grained mixtures of these minerals with common salt and kieserite. The economic bearing of the occurrences, together with questions of their mineralogy and genesis will be discussed in a paper now under preparation.

Steatite.

Jaipur State.

54. In addition to the locality of Morra long known for its steatite, Mr. Heron describes other and hitherto unrecorded localities where that mineral is extensively developed in thick beds of great purity. The new localities are Dogetha (Dagota), 2¼ miles N. E. of Raialo (lat. 27° 5'; long. 76° 15'), Gisgarh lat. 26° 53'; long. 76° 40'), and Kawa (lat. 26° 46'; long. 76° 32'). The Dogetha deposit is excavated

to a width of about 30 yards, but is probably wider, as the country rock on either side is not laid bare. It runs diagonally, dipping at 80° west by south, across the end of a hill and is only excavated for some 50 or 60 yards along the length of the bed in an open cutting. The steatite is very pure, milk-white or faintly tinged with green, with very thin films of pink ferruginous matter in some of the joints. The joints are irregular and allow of pieces up to one foot or so in length being extracted, but most of the material is in much smaller pieces and no particular effort is made to get large blocks. The deposit is quite structureless except for the jointing, and no clue could be obtained as to its origin; in no place was a junction with the surrounding rock seen. The cost of excavation is about one rupee for six or seven maunds. It is transported to Dosa station on pack bullocks at two annas per maund. Rs. 3,000 is said to be the annual rent paid for the quarry. From Dosa it is sent mainly to Amritsar and some to Cawnpore.

At Gisgarh the bed is only 2 feet thick and the material inferior to that of Dogetha. At Kawa only traces of steatite were noticed in a well.

With regard to Morra-bhandari, the original locality described by Hacket as the source of the stone used by the Agra stone-carvers, Mr. Heron describes the deposit as extending for 5 miles in the form of richer pockets in a stratum concentrated from talcose schist. One of these is mentioned as being about 25 feet thick. Work is only being done at one place 1 mile west of Morra (lat. 26° 49′; long. 76° 51′).

Water.

Itarsi.

55. At the request of the Railway Board, Mr. H. C. Jones, visited Itarsi in June, on behalf of the Great Indian Peninsula Railway, in order to report on a proposed scheme for a reservoir. The site chosen for the dam proved unsuitable owing to the porosity of all the rocks in the neighbourhood and no suitable site could be obtained.

Rajdaha, Manbhum district.

56. In December I paid a short visit to Rajdaha near Topchanchi in Manbhum district, to examine a site for a dam in connection with an important project for a water-supply for the Jherriah coal-field. It is proposed to build a dam across a small valley immediately

below the village of Rajdaha and thus to impound a large body of water. The site for the dam had been chosen where a belt of hornblende-gneiss crosses the valley; this appeared to offer a suitable foundation.

Wolfram.

Tavoy.

57. Mr. Page continued his investigations into the condition of the wolfram industry in Mergui and Tavoy. The absence of reliable maps has led to serious difficulties in the matter of granting licenses and leases and Mr. Page's work has been largely of a clerical nature with a view to preventing the confusion that inevitably follows the failure on the part of applicants to define exactly the boundaries of the concessions for which they apply. Mr. Page is preparing an *ad interim* report and it is hoped that by the end of the present field-season he will be in a position to make final recommendations.

GEOLOGICAL SURVEYS.

Bombay, Central India and Rajputana.

Mr. C. S. Middlemiss : Idar State.

58. Mr. Middlemiss continued his survey in Idar State, begun the previous season, and completed all the main portion of that State, so far as areas of solid geology are concerned, with the exception of a few strips and corners along the north and east boundaries, which will be finished off later in conjunction with other outlying parts of Mahi Kantha Agency. The area is included in the following sheets of the 1"=1 mile Bombay Survey (the numbers in brackets refer to the same sheets numbered according to the Central India and Rajputana Survey) :—Nos. 119, 143 (120), 144 (121), 145 (122), 146 (123) and 179 (150).

59. The mapping of the calc-gneisses of the Aravalli system, mentioned in the preceding Annual Report, was continued north of last year's area into the long strip of Idar territory lying between Udaipur on the east and Danta on the west. There, in the neighbourhood of Kherod (lat. 24° 14', long. 73° 3') an important modification takes place. Instead of being composed as in the Vadali neighbourhood of calcite, quartz, microcline, diopside, wollastonite, scapolite, etc., profusely penetrated by aplite and pegmatite

veins, it takes the form of a dark rock composed mainly of crystalline calcite penetrated on a very minute scale by *lit-par-lit* layers of basic hornblende-felspar material (amphibolite), the resulting complex being a precise reproduction in some of its varieties of the amphibolites described by Adams and Barlow in Canada[1]. This series, which may be called the Kherod amphibolite series, is folded along with garnetiferous mica-schists and phyllites, and seems to underlie to the west the ordinary calc-gneisses of the Vadali area. The full examination of these rocks is still incomplete in the direction of Posina.

60. Other modifications of the calc-gneiss series, with the production of massive idocrase at one locality, and thick beds of white pyroxene and other rocks at another, are referred to in more detail in a separate part of this report (*supra, p. 11*); whilst the steatite, asbestos and associated serpentine, magnesite, etc., of Kundol have already been noticed in the preceding annual report and in a short article by Mr. Middlemiss published in the same volume of the *Records*.

61. Several instructive examples, demonstrating the later intrusion of the Idar granite masses across the sharply truncated edges of the Aravallis with their included older granite veins, were specially noted this season, one being at the N. W. edge of the Dharol hill (lat. 24° 0′, long. 73° 2′) and another at Asai hill (lat. 23° 55′, long. 73° 3′). A few new types were noted among the older aplites and granite veins, one of which is a medium-grained granite with allanite in crystalline grains completely taking the place of the usual ferromagnesian constituents.

62. The exact lie of the Aravalli complex with reference to the succeeding Delhi quartzite is generally not very clear in Idar State, but at one locality near Khercha (lat. 23° 40′, long. 73° 24′) observed last season, the wandering strike directions of the former show complete discordance against and beneath the presumably younger massive Delhi quartzite. The latter itself, whilst building all the rather lofty and sturdy hill ranges of this part of the country, is also most intricately involved in foldings, twistings and crushings, whose complexity is such as to render any exact reproduction of them in section very difficult; the outcrop and strike are generally self-evident but evidence of dip in these rocks is not often reliable.

[1] Geol. of Haliburton and Bancroft areas, Ontario, Dept. of Mines, Geol. Surv. Branch, Mem. No. 6 (1910), pp. 157—172.

63. The Delhi quartzite again in turn appears to be succeeded on its eastern border by an extensive younger series of soft, thin-bedded and splintery schists or phyllites, of pale drab, yellowish and greenish colours, quite distinct from the Aravallis, and unlike them pierced by no plutonic intrusives, but only by numerous white quartz veins. These build a third type of country, distinct, on the one hand, from that of the alluvium-covered Aravallis, and on the other, from the massive ridges of Delhi quartzite. It consists of long, low, undulating hills with ribs of vein quartz, the whole making a confused, labyrinthine tract of low knolls and intricate stream-beds, the favourite haunt of the Bhils. In its further extension to the east, this series of phyllites merges into those of Dungarpur State east of Isri and Meghraj, where their survey is still awaiting completion.

Mr. H. C. Jones: Gwalior and Tonk.

64. Mr. Jones, continuing his survey of last year in Gwalior, proceeded to the southern part of the main area of that State which lies north-east of Bhilsa town (lat. 23° 31′, long. 77° 52′), and is contained in the 1 inch=1 mile standard sheets, Nos. 374, 375, 376, 392, 393, and 394 of the Central India and Rajputana Topographical Survey. Only towards the end of the season, in March, was he able to continue his survey still further north into a portion of Tonk State adjoining the Bhilsa district. The area surveyed, on its south-west border, marches with that already mapped in detail, partly by E. Vredenburg (season 1897-1898) and partly by C. S. Middlemiss, H. Walker and Sethu Rama Rau (season 1904-1905). The great diversity of Upper Vindhyan rock stages, from Lower Kaimur sandstone to Upper Bhander, so well exposed in that completed area, was not found, however, to continue into the ground surveyed by Mr. Jones, and which is now under review. The latter proved to be mainly Deccan Trap and alluvium, with here and there groups of isolated tabular hills composed solely of one or two members of the Upper Vindhyan sequence, namely, false-bedded, purple and mottled sandstone, judged to be of Lower Bhander horizon, underlain locally, as at Udepur (lat. 23° 54′, long. 78° 5′) by greenish and purple shales presumed to be the Ganurgarh shales, and at one place, namely, three miles south-west of Hydergarh Basoda (lat. 23° 37′, long. 28° 14′), by a limited exposure of siliceous lime stones. On account of the entirely detached, inlying character of the exposures, surrounded as they are on all sides by wide expanses of Deccan Trap and alluvial valleys, Mr. Jones

cannot be absolutely certain of the exact horizons of these rocks (some of which may possibly belong to the Rewa stage).

65. The country, which is a moderately level plain, lies at a general elevation of about 1,800 feet, diversified by isolated hills and hill ranges rising another 400 feet above that. These latter are mostly the sandstone as described above, generally horizontal, but dipping 2° or 3° north-west in the south-west part of the area, and dipping east near Udepur (23° 54′; 78° 5′). The Deccan Trap presents no new features and consists of superposed sheets of dark, fine-grained basalt without olivine and with amygdaloidal layers and interrupted rarely by a very thin and often disrupted bed of Intertrappean limestone and chart, which sometimes becomes a mere collection of residual blocks. No fossils were yielded by these Intertrappeans.

66. Ferruginous laterite and residual laterite lie in frequent but discontinuous patches, especially in the north-west parts of the area. Some fragments of an aluminous variety were noted near Hura (Saugor district). Good cotton soil covers most of the flatter parts especially those in the north of Bhilsa district.

Economic.

67. Nothing of special economic importance is reported. Excellent building and flag stones are of course obtained from the Vindhyans. Ferruginous laterite, once a source of iron, is now largely used as road metal.

Mr. A. M. Heron: Jaipur State.

68. Mr. Heron, having in previous years surveyed in detail Alwar State and the neighbouring geologically connected areas to the east, turned his attention during the last working season to the part of Jaipur State lying to the south and south-west of his original base of operations in Alwar. The area surveyed, besides a large portion of Jaipur, includes also the Tonk Pargana of Tonk State, the Chiefship of Lawa and certain detached villages of Bundi State (the Bundi and Lawa areas being completely enclosed by Jaipur territory). This large area is comprised within eighteen standard (1″=1 mile) sheets of the Central India and Rajputana Survey, namely, Nos. 229 to 232, 260 to 265, 288 to 292 and 316 to 318. Of these sheets Nos. 261 to 263, 289 to 292 and 316 to 317 have been completely surveyed geologically, and 264, 265 and 318 finished so far as Jaipur State is concerned.

69. The area, like that previously revised by Mr. Heron, had already over thirty years ago been surveyed by Hacket, and the geology and economic resources outlined in several publications by

that author.[1] Its re-survey was necessary, in continuation of the regular revision of Hacket's work in this area, for reasons explained in previous General Reports. Excluding sheets 288 and 316, mapped in previous years, the rest of the area stretching to the south and south-west is a vast alluvial and sandy plain with only very occasional, narrow, strike-ridges (*mala*) and strips and patches of rock with north-east—south-west alignments, rising out of that plain. Of these the Lalsot-Toda Bhim elongated ridge-mass stretches for over 40 miles in length, and has been mapped by Mr. Heron as "Delhi system", but described in his report as the Alwar series. Others again, stretching for even longer distances, and sometimes extremely attenuated, expose only the metamorphic Aravallis, with small areas of intrusive granite, pegmatite and quartz veins. In this newly surveyed region, outside sheet 288, none of the lower members of the Delhi system, namely, the Raialo quartzite and limestone, which come normally below the Alwars, have been recognised. Similarly, none of the series above the Alwar quartzite, namely, the Ajabgarh series and Hornstone Breccia have been certainly detected. Thus the Delhi system is here restricted so far as outcrops are concerned to its middle member, namely, the Alwar or Delhi quartzite series; but it is possible that the other lower and upper members may lie hidden beneath the alluvium.

70. Having revisited the old area of the Raialos, Mr. Heron finally rejects the tentatively expressed idea that the granite is intrusive into them, and now believes them to lie unconformably upon it. It seems now established, therefore, that the Delhi system lies unconformably above the Aravallis and above their intrusive massive granites, though certain pegmatite veins cut through all the systems including, though rarely, the Ajabgarhs.

71. Mr. Heron's report enters very clearly and fully into the description of the new areas. The metamorphic origin of the Aravallis is amply demonstrated by the varying amounts of alteration of them from hardened, though uncleaved, shales to coarsely crystalline biotite schists with staurolite or garnet in great quantity. The dark, impure, thin-bedded quartzites associated with them are deemed to be quite different from the Alwar quartzites (though sometimes marked as such by Hacket) and never like the latter showing ripple-marks. Strictly subordinate to the above are schis-

[1] *Rec. Geol. Surv. India*, Vol. X, pt. 2 (1887), Vol. XIII, pt. 4 (1880), and Vol. XIV, pt. 4 (1881).

tose conglomerates, grits and impure argillaceous limestones and epidiorites of uncertain origin. The general dip is north-west at high angles of from 30° to vertical. The rocks intrusive in these are quartz veins with a small amount of tourmaline, bosses of granite, slightly pressure-foliated, medium-grained and porphyritic, with a groundmass of microcline and a micrographic intergrowth of quartz and felspar; aplite veins; and pegmatites in masses of all sizes from half an inch to many yards across and of medium to extremely coarse grain, their mineral constitution only differing from that of the granites by the presence of tourmaline. The Alwar quartzite representatives of the Delhi system are caught up among the Aravallis in a double or triple set of synclinal folds combined with anticlines by rapid variation in the pitch of the axes, and some of them resemble more nearly those of the Biana Hills (described last year) than those of Alwar.

72. Only one doubtful occurrence of a black brecciated slate near Podampura (lat. 26° 51′, long. 76° 49′) may represent the Ajabgarh series. The rest of the country is a vast expanse of light loam and sand hills, the latter heaped up by the prevailing winds on the western faces of the rocky ridges, but not much resembling the travelling dunes of more desert-like areas, inasmuch as they all bear a scanty vegetation of tall "munj" grass and various small shrubs.

Economic.

73. In addition to iron, kaolin and steatite (*see* pp. 19, 21), Mr. Heron records some trifling occurrences of mica; quartz is also referred to and the garnet workings long since closed, at Toda Rai Singh and other villages to the south and west of Rajmahal.

Mr. N. D. Daru: Dungarpur.

74. The survey of the State of Dungarpur was continued by Mr. Daru, who attributes most of the rocks met with to the Aravalli system, the chief types include ortho-gneisses, schists, phyllites, quartzites, boulder-beds and crystalline limestones; Mr. Daru has not yet been able to subdivide these.

Burma.

Mr. E. Vredenburg.

75. The Burma party has now been strengthened by the addition of a Superintendent, and Mr. Vredenburg took charge of the party towards the end of the year under review.

Mr. P. N. Datta: Kyaukse and Meiktila.

76. Mr. P. N. Datta was engaged in the survey of the eastern parts of the Irrawaddy valley lying in the districts of Kyaukse and Meiktila and bounded on the east by the hills of the Shan States. The rocks met with consist of young clastic deposits, referred to the Pegu series on the west, and a group of older sedimentary rocks intimately associated with and altered by intrusive granite on the east. The older rocks consist of shale, sandstone and limestone, all frequently metamorphosed; in the absence of fossils, there is no evidence of their age, but Mr. Datta suggests that it may be Palæozoic. Felsite and andesite are also said to occur in this region, but their relationship to the other rocks is not stated.

Mr. G. de P. Cotter: Yenangyaung and Minbu.

77. While acting as "Oilfields Officer" at Yenangyaung during the early part of the year, Mr. Cotter visited the steatite mines in the Arakan Yoma and made some notes on the country traversed; no new facts, however, were brought to light. During the latter part of the year, he took up the systematic geological survey of the western part of the Minbu district including Hpa-aing and the eastern flanks of the Yoma; rocks of eocene and of so-called "lower eocene" age were found, the former yielding the usual "Khirthar" fossils. Serpentine intrusions are numerous. Owing to the unhealthiness of the season, Mr. Cotter was obliged through illness to interrupt his work, temporarily transferring operations to a less malarious area until the season should be more advanced.

Mr. H. S. Bion: Upper Chindwin.

78. During the latter part of the year, Mr. Bion took up a survey of the auriferous gravels of the Chindwin. His work has been noticed under *Gold* (*supra*, p. 18).

Sub-Assistant Sethu Rama Rau: Minbu and Pakokku.

79. Sub-Assistant Sethu Rama Rau continued the mapping of the Tertiary beds on the west of the Irrawadi in the districts of Minbu and Pakokku. He completed the survey of the area covered by sheets $84\frac{K}{11}$ and $84\frac{K}{15}$ with the exception of the part already surveyed by Mr. Cotter. In the Minbu district he added the geology to parts of sheets $84\frac{L}{5}$, $\frac{L}{6}$, $\frac{L}{9}$ and sheet 110.

Burmo-China Frontier.

80. The results of the geological traverses made by Mr. Coggin Brown a few years ago in the neighbourhood of the Burmo-China frontier about Tengyueh have now been embodied in a paper which will be published in a subsequent part of these *Records*.

81. The rocks met with are classified by Mr. Brown into six subdivisions, *viz.* (in descending order)—

(6) Recent deposits;
(5) later Tertiary deposits of the Taping, Möng-hsa Möng-wan and Teng-yueh valleys;
(4) eruptive volcanic rocks of the Teng-yueh area;
(3) metamorphic rocks of the Kao-liang series;
(2) intrusive granites of the upper Taping valley;
(1) gneisses, schists and crystalline limestones of the frontier hills.

82. The crystalline series (1) covers the greater part of the country between Bhamo and the Salween; in the neighbourhood of Teng-yueh it is hidden as a rule by younger bedded deposits, but inliers of the old crystalline surface often appear. Granite (2) also occurs in considerable quantity.

83. The metamorphic series (3) consists of quartzites and phyllites, very similar to, and probably of the same age as, the Chaung Magyi series of the Northern Shan States.

84. The eruptive volcanic rocks, of which a separate description has been written by Mr. R. C. Burton (*supra*, p. 12) consist of andesites, basalts and pumice. They fall into an "older" and a "newer" group, the former consisting of grey, close-grained porphyritic andesites, which have a characteristic platey structure and are often folded. They are much older than the members of the "newer" group, although no age is assigned to them, but Mr. Brown seems to contemplate the possibility of their being as old as Palæozoic. The newer group consists of massive andesites, which are of Tertiary age and are again older than the black slaggy lavas of the still existing, though no longer active, vents.

85. The later Tertiary, as well as the Recent, deposits of interest are chiefly of lacustrine origin, the older being similar to those of the Northern Shan States and Tongking and probably of late Tertiary, and perhaps partly pleistocene, age.

86. Hot springs are very numerous in the district of Teng-yueh and are regarded as the last manifestations of the earlier intense volcanic activity.

Central Provinces.

Dr. L. L. Fermor, Messrs. H. Walker, C. S. Fox, R. C. Burton and Sub-Assistant M. Vinayak Rao.

87. The party as constituted for the season 1911-12 consisted of Dr. Fermor, Messrs. H. Walker, C. S. Fox, and Sub-Assistant M. Vinayak Rao; Mr. R. C. Burton having also been added for the season 1912-13.

Dr. L. L. Fermor and Mr. C. S. Fox: Chhindwara district.

During the early part of the year, work was carried out by Messrs. Fermor and Fox in the valley of the Kanhan river and its bordering hills. Owing to the intricacies of the boundaries between the Deccan Trap and the Archæan granites and gneisses and the thickly wooded and sparsely inhabited character of the ground investigated, work was necessarily slow, but a total of some 300 square miles was mapped on the one-inch scale (Sheet 53, C. P. Survey).

The Archæan floor below the Deccan trap.

88. There is nothing to add to the account of the Deccan Trap formation given in the previous report, except to refer to the gradually decreasing elevation of the base of this formation as one passes from north to south. Thus, near Pardhan Ghogri the elevation of the base of the trap is 2,075 feet, whilst at Koprawari, only some 13 miles further south, it is about 1,400 feet. At the northern end of the valley the Archæan rocks are found to join the main strip of granites running westward from Chhindwara. It is evident from this and from the fact that granites and gneisses crop out on the Satpuras to the east of Seoni, that the Satpura range, which at first sight appears to owe its elevation to the presence of superposed flows of Deccan Trap lavas, is really a feature of the pre-Trap Archæan surface. Although there is a gradual decrease in the elevation of the boundary between the Deccan Trap and the Archæan in passing from north to south, yet this change of elevation is locally very irregular and by means of aneroid readings it has been possible to detect many features of the pre-Deccan Trap topography. Thus the basal flow of Deogarh Hill and the underlying Lameta sediments, with those to the south-west of this hill, occupy an old river valley at least 50 feet deep.

Nature of Lameta rocks in Chhindwara.

89. Detailed examination of this boundary is necessary owing to the local variations in the thin band of rock usually intervening between the Deccan Trap and the underlying gneisses. This band must be correlated with the Lametas, since it agrees in many respects with occurrences seen in other parts of India; but as the result of detailed work it has been found that by far the larger proportion of this Infra-trappean formation is not a sediment, but a rock of chemical origin formed either by the silicification or by the calcification of the underlying gneisses. Every gradation has been found from a fresh porphyritic gneiss, through a similar rock partially veined by chert and calcite, to a more completely replaced stage, in which the gneiss is seen in isolated patches in a network of secondary calcite, finally passing into a capping of typical siliceous limestone, to be distinguished in no way from the Lameta limestone of other parts of India.

and at Lameta Ghat.

90. In November 1912, Dr. Fermor paid a brief visit to Lameta Ghat in the Jabalpur District, the original locality from which the rock took its name; here he found the limestone to be lithologically indistinguishable from the final products of the calcification of the gneisses in Chhindwara. The limestone of this locality rests, however, upon the sedimentary Jabalpur series of the Gondwana system; it will therefore be necessary to make a very careful study of the Lameta outcrops at Lameta Ghat and near Jabalpur in order to solve this problem satisfactorily. Meanwhile it is interesting to note that in thin sections under the microscope the limestone of Lameta Ghat itself shows evidence of secondary calcification. Provisionally, therefore, it may be regarded as probable that a considerable, if not large proportion of the rock mapped as Lameta in different parts of India is of chemical origin. This would explain the extraordinary scarcity of fossils in the Lameta formation. A great variety of rocks have been found thus, replaced either by silica or by calcite. Amongst them may be enumerated several varieties of granite and gneiss also hornblende-schist and crystalline limestone.

Sedimentary Lametas.

91. The detailed work along the Infratrappean boundaries has shown, however, that true sediments also occur. These are usually grits of various degrees of coarseness and are probably to be referred to the Lameta

formation. At two localities Dr. Fermor succeeded in finding fossils. One of these was a specimen of *Turritella ?* in a piece of silicified rock near the hamlet of Kotmi, but a prolonged search did not lead to the discovery of any further specimens. Whilst numerous specimens of *Paludina* were obtained from a siliceous grit at the second locality (about two miles north-west of milestone 23 on the Chhindwara-Nagpur road). The only exposure of the Lameta formation of any considerable size is that occupying the valley to the south of Deogarh Hill: it consists partly of grits and partly of clays.

92. The evidence concerning the date of formation of these calcareous and siliceous rocks is not yet regarded as conclusive by Messrs. Fermor and Fox, but in all probability the silification was effected by solutions derived from the overlying Deccan Trap formation. It is possible that the Lameta limestones have been formed by the superficial replacement of the gneisses prior to the eruption of the Deccan Trap and the deposition of the sedimentary Lametas. If this deduction be correct the calcification and the silicification of the gneisses must be assigned to different periods, the silicification due to the Deccan Trap having affected both the fresh gneisses, the partially calcified gneisses, the so-called Lameta limestones, and the true Lameta grits, fossiliferous and unfossiliferous. In one place this silicification by the Deccan Trap was found to be accompanied by the introduction of heulandite into both the gneisses and the silicified limestones. But, on the other hand, it is much more probable that the calcification has been effected by solutions derived from the overlying Deccan Trap, in which case the calcification and silcification are to be regarded as two stages of one series of chemical processes.

The Archæan rocks;

93. The Archæan rocks in the area mapped are almost entirely granites and ortho-gneisses, metamorphosed sediments being practically absent, until the south-east corner of the sheet is approached, where, in the neighbourhood of Nautal, crystalline limestones are found in great variety. The Archæan gneisses are divided into two sections by a zone of intense crushing marked by rolled out and mylonitised gneisses stretching for 15 miles in a west-south-west direction from a point two miles south of Monkher to a point two miles south-south-west of Dhanora. This zone of crushing is accompanied by a strike fault, and the gneisses have been locally brecciated, and to a large extent replaced by white

vein-quartz. In the eastern section this fault-breccia is from 50 to 100 feet wide and gives rise to steep bluffs and well-marked ridges; but in the western section it is either completely absent or only from a few inches up to 5 feet wide. The rock immediately north and south of the quartz-breccia is a hornstone-like rock, which, being really a mylonitized gneiss, has been termed hornstone-gneiss. This belt of crushing extends for about a mile to the north of the quartz reef, the degree of mylonitization of the gneiss decreasing with distance from the quartz-breccia. The mylonitized gneisses are succeeded to the north by intimately associated porphyritic pink biotite-gneisses and melanocratic biotite-hornblende-gneisses rich in sphene. Still further north the foliation becomes less marked and the rocks may in places be termed porphyritic granites. On the south side of this quartz-breccia reef the rocks are mylonitized for a short distance and then give place to well-foliated schistose biotite-gneisses; and from the field evidence obtained it is deduced that the typical schistose biotite-gneisses of the Sausar Tahsil of this district may be merely foliated forms of the porphyritic granites of Chhindwara. The belt of crushing seems to be a fairly sharp dividing line between the porphyritic granite on the north, with its mylonitised and rolled-out derivatives, and the schistose gneisses on the south. Whereas the terms granite and gneissose granite would frequently be applied to the rocks on the north of the fault, the term gneiss is more generally applicable to those on the south.

Their mutual relationship.

94. Amongst the rocks south of the fault there are many varieties extremely rich in hornblende with every gradation between coarse-grained biotitic and coarse-grained hornblendic gneiss, whilst near Nautal a small area of true syenites has been found. Several occurrences have been found, also, of microcline-rocks, which must be regarded as an extreme variety of syenite. In many places throughout the Kanhan valley and that of the Nakta nala there are intrusions of pegmatites and of rather fine-grained granites, and although both these rocks seem to be on the whole distinctly younger than the porphyritic granites and their schistose and gneissose derivatives, yet the evidence obtained indicates a general relationship not only between the fine-grained granites and the pegmatites, but also between each of these rocks and the porphyritic granites and associated gneisses, and points to the probability that all these granites and orthogneisses are magmatic

relatives and have been derived from one magma. This idea, however, of a common magmatic origin does not preclude the possibility that some of the gneisses may be of considerably greater age than the porphyritic granites and their derived gneisses.

Pegmatites.

95. The pegmatites are of considerable interest. Some of them contain only pink potash-felspar, whilst others contain both potash-felspar and a white plagioclase, and still others contain only the plagioclase. Some of the pegmatite dykes are very coarse-grained in parts and have the constitution of fine-grained granites in other parts; one dyke in the Nakta nala consists centrally of a fine-grained granite, whilst both edges are very coarsely crystalline and have in places the constitution of a graphic granite.

Epidiorites and basalt dykes.

96. In the neighbourhood of Lawaghogri Mr. Fox found a series of lenticular outcrops of epidiorite intercalated along the foliation planes of the gneisses. They show every gradation between a slightly altered dolerite and a hornblende-schist. In the same neighbourhood Mr. Fox has also traced several basalt dykes of Deccan Trap age traversing the Archæan rocks. In one case, near Narainghat one of these dykes is directly connected with the overlying flow of basalt.

Continuity of fault.

97. The belt of mylonitization and fault-breccia already referred to is covered over at either end by the Deccan Trap lava flows and it is probable that it continues for some distance beneath the trap. If it continues to the north-east it should, if still existent, reappear somewhere in the neighbourhood of Seoni.

Mr. Walker: Betul district.

98. Mr. Walker was engaged in surveying the parts of the Betul district represented by Standard sheets (1″=1 mile) 36, 37 and 53. The rocks met with belong to the same general groups as those of Chhindwara and include chiefly gneisses, Dharwar schists and Deccan trap, with Infratrappean and Intertrappean beds in places. To the south of a line drawn from Nilajhar (21° 55′: 78° 32′) to Amla (21° 55′: 78° 10′), the only rock found is Deccan trap, whilst to the north of this line gneisses and schists occur. On the whole, the gneisses play only a subordinate part; they consist of schistose biotite-gneiss with occasional patches and veins of aplite and intrusive masses of epidiorite and hornblende-schist.

Dharwar schists are infolded with the gneiss along its margins. The Dharwar rocks comprise three general types, *viz.*, argillaceous sediments, as represented by phyllites, to the north of Kalmeshara (22° 2′ : 78° 21′); micaceous quartz-schists and quartzites (metamorphosed arenaceous sediments) to the south of the same place; and old intrusive rocks now represented by epidiorites similar to those of the Kanhan valley, and found at Bordhai (22° : 78° 23′) and Harnia (21° 59′ : 78° 22′).

99. Of the Infratrappean beds, Mr. Walker regards five small exposures, consisting of conglomerates, grits and clays, as perhaps of true sedimentary origin; between Nilajhar and Banga (21° 55′ : 78° 25′) the trap is usually underlain by limestone and chert, which as in Chhindwara, are regarded as due to secondary replacement of the underlying crystalline rocks through the contact action of the trap.

100. The Deccan trap is from 400—500 feet thick; the upper and lower flows are vesicular and crowded with geodes of quartz and chalcedony, but zeolites are rare. A slight dip to south-west has been noticed in the basalt flows. Basalt dykes have been found penetrating the crystalline rocks.

101. Intertrappean beds occur at three horizons; they are of the usual type and are often fossiliferous.

102. The schists and gneisses of the Bel valley show signs of considerable disturbance: faults are common, and, in the Dharwar schists, are accompanied by brecciation; this has given rise to a series of ridges, which form conspicuous features in the local topography.

Sub-Assistant Vinayak Rao: Seoni district.

103. After accompanying Dr. Fermor for some six weeks and having become familiar with the sections in the Nakta nala, Sub-Assistant M. Vinayak Rao was sent to commence work on sheet 90 in the Seoni district, with special instructions to search for the continuation of the strike-fault and belt of crushing. He succeeded in finding crushed gneisses and in one place a breccia, approximately where expected. But the dynamic effects seem to be feebler in Seoni than in Chhindwara and split up into more than one belt. In conformity with this the general distinction between more granitic rocks on the northern side of the crush zone and more gneissose rocks on the south is less readily apparent than in the Kanhan area. In the time at his disposal Mr. Vinayak Rao

nearly completed a preliminary survey of the whole of this sheet. the boundaries between the Deccan Trap and Archæan rocks being largely obscured by soil. To the south of Seoni a considerable area of laterite was discovered resting on the Deccan Trap, the thickness of the laterite being in one place as much as 140 feet.

104. In his progress report Mr. Vinayak Rao reports the discovery of two dykes near the village of Suktara, two miles north-west of Kanhiwara Railway Station. These have each a very irregular course and vary in width from a few inches to 2½ feet; they are of tachylytic character, with chilled glassy borders.

Kashmir.

Messrs. C. S. Middlemiss and H. S. Bion: Kashmir.

105. During the summer months Mr. Middlemiss continued the revision of the geology of Kashmir, in extension of his work in 1910. Mr. H. S. Bion was placed, during his first field season, with Mr. Middlemiss, and proved himself an energetic and capable observer. Work was taken up in the neighbourhood of Srinagar and continued round the north end of the valley, including also a portion of the Kishenganga drainage, during the first months of the season, and afterwards in the direction of the Marbal, Hoksar and Changam passes at the south-eastern extremity of the valley. Extensive new collections from the various old and some new horizons of the Silurian-Trias sequence have been made, and the mapping of the area in as much detail as possible carried on to a point where another season, it is hoped, will see the conclusion of the revised survey of the valley of Kashmir proper, that is to say, of all that portion lying within the Jhelum drainage area. It is also hoped that the new 1 inch=1 mile maps recently made by the Survey of India will be used in this work, which will serve as a valuable basis for the larger and more difficult task of mapping the complicated metamorphic areas to the north, including Baltistan, the Karakoram and the Hindu Kush.

106. Among special results attained, the following may be mentioned: at Tregam (Trigamma) the limestone masses, as also those shown at intervals beyond to the north into the Kishenganga drainage and west again near Zunaresh, were found to be interbedded with the old slate system, and not to belong to the Zanskar system. This was verified by finding at several horizons

in the slates interbedded with the limestones a Silurian *Orthis* fauna similar to that of Gugaldar, Gudramer and the Margan pass; the agglomeratic slate series, which comes between the Fenestella series and the Panjal Trap, and which hitherto had yielded no fossils, has now been found to contain at least two life zones, one coming a few feet below the base of the Panjal Trap and the other much lower down. Both are characterised by a rich *Syringothyris* fauna, together with a *Spirifer* allied to *S. Lydekkeri* Dien., *Fenestella*, *Productus* and *Camarophoria*. The lower horizon has so far been found only in the Marbal valley on the way towards the pass; it is very rich in material and of considerable thickness. The upper one is much thinner and is found in the Marbal valley and also at Nagmarg in Lolab.

107. A *Glossopteris* flora, with *Gangamopteris* and *Psygmophyllum* has also been found just below the Panjal Trap in the Nagmarg sections.

108. In the Manasbal and Bandipur sections, Lydekker's conclusions that no Kuling series is there represented above the Panjal Trap was confirmed, and the most probable inference drawn that the volcanic activity of the Panjal Trap epoch extended up to the base of the Upper Trias in those parts, whilst again in the Imbersilwara hill mass, trap appears to be interbedded with the Upper Trias in a remarkably clear section.

109. A very rich Muschelkalk fauna has been found at many new places in the south-eastern part of the valley. In the Marbal valley the section from Karbodra down to Prumu in the Tansan river shows a wonderfully clear exposure, of about 20,000 feet thickness, through the Silurian-Trias sequence in fine normal folds of 15,000 feet double amplitude.

110. It is difficult to exaggerate the importance to Himalayan stratigraphy of the many discoveries made by Mr. Middlemiss in Kashmir during the last few years, for they have led to the solution of all those vexed questions which have hitherto barred the way to a satisfactory correlation of the various systems in the Jhelum basin with their less complicated representatives in Spiti and Kumaon. Of the work now under review the most striking feature is the complete manner in which Mr. Middlemiss has worked out the age of the Panjal Trap which he has shown to extend from Lower Gondwana to Upper Trias in some places, whilst disappearing in others at the end of the Permian period.

Punjab.

111. From February until May 1912, Dr. G. E. Pilgrim was at work on the northern edge of the Salt Range, where he mapped in detail the ossiferous areas round Chinji and between Hasnot and the river Jhelam, collecting fully from the various stratigraphical zones. The following results of his observations are regarded by Dr. Pilgrim as of chief importance :—

Dr. G. E. Pilgrim: Salt Range.

(1) the occurrence at a low horizon in the Middle Siwaliks at Nagri of a fossil fauna believed by Dr. Pilgrim to be intermediate in character between that of Dhok Pathan and that of Chinji;

(2) the apparent absence of *Hipparion* from the lower 1,500 feet of the Chinji beds;

(3) the existence of unfossiliferous strata of Siwalik type, 1,700 feet thick, below the Chinji fossiliferous zone. This had previously been noticed by Mr. Vinayak Rao, who had, however, assigned the beds to the Gaj;

(4) in the Chambal ridge near the Jhelam river, a very distinct unconformity between the Upper and Middle Siwaliks. Many feet of Middle Siwalik strata are entirely missing including the fossiliferous horizon of Hasnot, the equivalent of that of Dhok Pathan. Going towards Hasnot the upper beds gradually come in, and the unconformity diminishes, though it is nowhere, perhaps, entirely absent;

(5) the fossils of the basal beds of the Upper Siwaliks at Tatrot, Kotal Kund, and some other localities have been erroneously united by previous collectors with those of the Middle Siwaliks of Hasnot, and Dr. Pilgrim now considers it necessary to remove from the Middle Siwalik fauna *Hippohyus*, *Sus giganteus*, certain bovines allied to *Bos* and *Anoa* and most of the *Hippopotamus* remains. These occur in the basal beds of the Upper Siwalik associated with *Hipparion*, *Stegodon*, and *Mastodon sivalensis*, it being noteworthy that no trace of either *Equus* or *Elephas* has been found.

112. Dr. Pilgrim considers that these facts, taken in conjunction with the recent discovery by Dr. G. Schlesinger of *Elephas*

planifrons in a low zone of the middle pliocene near Vienna, afford additional evidence for the pontian age of the Middle Siwalik fauna of Dhok Pathan and Hasnot. He proposes the following classification for the Siwaliks of the Salt Range, based partly on his past season's work and partly on the collections made from the Simla hills in 1911 by Mr. Vinayak Rao:—

			Feet above base.
Upper Siwalik	Boulder-bed zone.	With *Camelus Equus, Elephas hysudricus.*	15,000—17,000
	Pinjor zone .	Pebbly sandstones with *Hipparion* and *Elephas planifrons.*	11,500—15,000
	Tatrot zone .	Conglomerates and grits with *Hipparion, Hippopotamus, Hippohyus* and *Mastodon sivalensis.*	10,000—11,000
Middle Siwalik	Bhandar beds	Unfossiliferous sandstones and clays.	9,500—10,000
	Dhok Pathan zone.	Sandstones and clays with *Mastodon, Stegodon, Tetrabelodon, Hipparion,* large antelopes and giraffoids and *Tragocerus.*	8,500—9,500
	Nagri zone .	Sandstones and clays with *Hipparion,* large antelopes, *Giraffokeryx* and a large giraffoid.	5,500
Lower Siwalik	Upper Chinji zone.	Red nodular clays and sandstones with *Tetrabelodon, Hipparion, Hyaena, Hyotherium, Giraffokeryx, Protragocerus,* and a large antelope.	3,200—4,000
	Lower Chinji zone.	Red nodular clays and sandstones with *Tetrabelodon, Hyotherium, Giraffokeryx, Protragocerus* and small antelopes.	1,700—3,200
	Lower Manchhar zone.	Sandstones and concretionary beds, unfossiliferous in the Salt Range: in Sind with *Brachyodus* and *Hyoboops.*	Basal beds.

PRELIMINARY NOTE ON GARNET AS A GEOLOGICAL BAROMETER AND ON AN INFRA-PLUTONIC ZONE IN THE EARTH'S CRUST. BY L. LEIGH FERMOR, D.Sc., A.R.S.M., F.G.S., *Superintendent, Geological Survey of India.*

Introductory.

The following notes were originally intended merely to summarise certain speculative investigations pursued by me in Calcutta in July-September 1912. The whole matter is being dealt with at greater length in a memoir, which, owing to various circumstances, cannot be made ready for the press for some little time. I have, however, investigated the available facts in sufficient detail to feel fairly confident of the general truth of the results herewith presented, although their subsequent development will doubtless lead to certain modifications. The line of thought, commencing with the classification of the Kodurite series, and leading rapidly through the consideration of the conditions of the formation of garnets to the deduction of the existence of a garnetiferous infra-plutonic zone of rocks, and to the origin of the chondritic structures of meteorites—pressure being the predominant factor considered,—ended naturally and logically with the consideration of this physical factor in the evolution of the elements. Certain interesting conclusions have followed in this last branch of the subject, but, with the exception of the case of radium and uranium, I prefer to avoid any further allusion to them for the present; for it is inadvisable for a petrologist to publish without more mature consideration the results of a flying expedition into the realms of physical chemistry, where rapid advances in our knowledge of the constitution of matter are constantly being made and where only the specialist may venture with confidence.

The original manner of compilation of this summary is responsible for the lack of references to literature, whilst my absence from headquarters prevents my adding them now; but such references seem unnecessary in a general summary of conclusions.

The place of kodurite in the quantitative system of classification.

In a paper published in the previous volume of the *Records*, I attempted, by means of the quantitative system of Messrs. Cross Iddings, Pirsson and Washington, to classify the kodurite series of rocks found in the Vizagapatam district, and arrived at the conclusion that this system of classification was not suited to the purpose. In making this attempt, it was necessary to convert the chemical analyses of kodurite and garnet (spandite) rock into the standard mineral composition or *norm* of the American authors. Typical kodurite is composed of orthoclase felspar, spandite (manganese-garnet) and apatite. The norm was found to contain orthoclase, leucite, anorthite, hedenbergite, wollastonite, tephroite, magnetite, ilmenite and apatite; whilst spandite-rock, when converted into its norm, is expressed as a mixture of anorthite, hedenbergite, akermanite, fayalite, tephroite and magnetite. The question naturally arose why the spandite-rock, for instance, had crystallised as such, and not as the complex mixture constituting its norm. A calculation of the specific gravity of the mode and norm in this particular case showed that garnet-rock occupied 20 per cent. less room than its norm, whilst the kodurite showed a 10 per cent. smaller volume when crystallised as the mode. This, of course, indicates at once that the conditions favourable to the formation of kodurite rather than of its norm are those requiring a decrease in volume, namely, those of high pressure.

Garnet as a geological barometer.

If this be the true interpretation, then garnet is, in many cases, to be regarded as a geological barometer, and the various rock series associated with the kodurite series in the Vizagapatam district may also be expected to contain garnets. This is found to be the case. Khondalite is composed of quartz, graphite, sillimanite and garnet. The common gneissose granites of the district are garnetiferous biotite-gneises. The charnockite series, which is normally free from garnet, is often in this area very rich in garnets. A continuance of speculation on these lines soon suggested that eclogite must be the high-pressure form of gabbro; this is confirmed by the specific gravities and chemical analyses of the respective rocks. The deeper one goes into the earth, the greater does the pressure become, and therefore the more favourable must the conditions be for the formation of garnets. Garnet has the general formula $3RO.R_2O_3 3SiO_2$, and since its formation must be favoured by pressure its average abundance should increase with depth below the surface of the earth, so long as sesquioxides, such as Fe_2O_3, Al_2O_3 and Cr_2O_3, are present to provide the radicle R_2O_3 in the garnet formula. It is customary, however, to regard the plutonic rocks, which are typically non-garnetiferous, as the deepest known rocks. But the chemical analyses of the majority of plutonic rocks show the presence of sesquioxides of iron and of aluminium, indicating that under high pressure such rocks should become garnetiferous. Therefore it seems legitimate to postulate the existence below the plutonic rocks of a shell characterised by garnets wherever a sesquioxide radicle exists. For this shell I suggest the term *infra-plutonic*.

The infra-plutonic zone.

Any rock in the infra-plutonic zone would probably have as large a proportion of its constituents as possible arranged in the form of garnets, and the protoxides, silica, and excess of alumina, if any, would crystallise out as felspars, quartz, and ferro-magnesian silicates free from sesquioxides. In this infra-plutonic zone, which must lie at very considerable depths, both temperature and pressure must be high, and the tendency must, therefore, be for those reactions and re-arrangements to take place that are accompanied by reduction of volume and absorption of heat. The formation of garnet from other minerals, such as pyroxenes, olivines, and iron-ores, is always accompanied by a decrease in volume; and it seems customary, and doubtless is correct, to assume that the reaction is endothermic, although, as far as can be discovered no experimental verification of this supposition has been made.

Its characteristic minerals.

One at once searches, of course, for other minerals that might be characteristic of this infra-plutonic zone. This branch of the subject has not yet been investigated in detail; but in the case of carbon it seems obvious that the graphite of the higher zones of the earth's crust will probably be represented by diamond in the infra-plutonic zone, on account of the high density of the latter mineral. It is thus deduced that garnet and diamond will be two of the characteristic minerals of this zone. It is supposed that in the infra-plutonic zone the pressure is normally sufficiently high to keep the rocks in a plastic-solid condition, and is transmitted in a manner somewhat analogous to hydrostatic pressure; this pressure has, of course, been termed isostatic.

The infra-plutonic rocks of the earth's crust.

A release of pressure over any given portion of the infra-plutonic shell would allow the liquefaction of that portion of the shell under the high temperatures prevalent; such liquid rock, on being intruded into the higher zones of the earth's crust, would then solidify under less pressure as a plutonic rock. It seems, therefore, that, under normal circumstances, we should not expect rocks from the infra-plutonic zone to reach the surface of the earth without changing into the plutonic form. But in those circumstances, doubtless, comparatively rare, in which the isogeotherms are lowered more rapidly than the pressure, it can easily be imagined that the rock may be able to cool in its infra-plutonic form and then, by subsequent earth movements and denudation, be exposed at the surface. The eclogites may be regarded as the commonest example of infra-plutonic rock, and perhaps the diamond pipes of Kimberley are directly connected with the infra-plutonic zone. It is interesting to note that diamonds, where found *in situ*, normally occur in basic, and often garnetiferous, rocks.

In some cases, the balance of pressure and temperature must be so adjusted that a partial release of pressure on an infra-plutonic rock allows only the outer shells of the garnets to break down into pyroxenes, olivines, iron-ores, etc.; some kelyphite zones may be regarded as evidence of this process.

Infra-plutonic magma reservoirs.

We must, therefore, assume that in the infra-plutonic zone the basic rocks are present as eclogites, and the more acid rocks as garnetiferous granites. Harker, in his *Natural History of Igneous Rocks*, postulates the existence of inter-crustal magma-reservoirs, which are normally solid, but become liquid on release of pressure. My conception of an infra-plutonic zone extends Harker's view of scattered magma reservoirs, with walls, the nature of which are not considered, to a continuous shell round the earth, the whole of which shell is a potential magma. This shell, being composed of rocks of the consistency of a plastic solid, may afford a cushion upon which the isostatic operations of the earth, believed in by some geologists, have their foundation. Any portion of this shell may become a reservoir on reduction of the superincumbent pressure. Later on, the particular portion so liquefied may become solid again. Subsequent tectonic movements may cause the liquefaction of another patch of this shell, the limits of which do not coincide with, although partly overlapping, those of the previous reservoir. During the history of the earth, there may have been, owing to changes in the tectonic conditions of its crust, a gradual migration from one part of the infra-plutonic shell to another, of the areas in which liquefaction of this shell is likely to occur.

Magmatic differentiation.

This hypothesis of the shifting of potential magma-reservoirs sympathetically with tectonic movements further suggests a possible factor in magmatic differentiation. On the analogy of meteorites one may regard the earth's crust as becoming, on the average, more basic in depth, the composition of the infra-plutonic zone thus being generally basic rather than acid. If it be legitimate to assume that the rocks of this zone ever had a generally uniform composition, then it is necessary to explain how a primary differentiation into acid and basic magmas can have taken place. If one examines the analysis of any rock from the point of view of its possibility of yielding garnets under pressure, it will be seen that certain of its constituents, *viz.*, CaO, FeO, MgO, MnO, Al_2O_3, Fe_2O_3, Cr_2O_3, and silica, may be utilized in the formation of garnets; whilst certain other constituents, particularly the alkalies, are unsuitable. Let us now suppose that a reduction of pressure causes liquefaction of a certain portion of infra-plutonic shell possessing a relatively intermediate composition. When the pressure on this section again increases, it will cause resolidification; but it is not inconceivable that during this process the tendency of certain protoxides to compound with sesquioxides and the required amount of silica to form garnets —thus taking up a portion of the increased pressure by a reduction in volume—may cause these very constituents, in an attempt to escape from the pressure, to migrate and leave behind a more acid residuum. In a portion of the infra-plutonic shell, where there happens to be a balance between the temperature and pressure leading to many alternations between the liquid and solid phase, it is possible that cumulative effects may in this way result, leading to a primary differentiation into acid and basic rocks.

Origin of meteorites.

This speculation concerning the constitution of the earth's crust naturally leads to the consideration of meteorites, and in a preliminary note on the origin of these bodies, read before the Asiatic Society of Bengal (J.A.S.B., VIII, No. 9, pp. 315—324 (1912)), I have advanced reasons for supposing that chondrules, so abundant in many meteorites, were formerly garnets, and that the chondritic meteorites represent rocks derived from the infra-plutonic zone of some disrupted celestial body. A sudden disruption of this celestial body would cause a sudden release of pressure, with the consequent melting of the garnets in the highly heated infra-plutonic zone into liquid drops scattered through a matrix of solid enstatite and olivine. The rapid cooling following upon the scattering of the fragments of this body would lead to a rapid freezing or congelation of these liquid garnets with the formation of the characteristic structures of chondrules. The protoxides and silica of the original garnets have crystallised out as olivine and enstatite, and the surplus sesquioxides have been expelled to the periphery of the chondrules, where they are now visible in the form of rims of metallic nickel-iron, the reduction of the expelled ferric oxide being presumably due to the presence of carbon, hydrogen or carbon monoxide. Other evidences of release of pressure are to be found in the iron meteorites. Thus cliftonite was formerly diamond; this has suffered a paramorphic change on reduction of pressure whilst the temperature was still high. These conclusions from the petrological point of view agree with the latest views of some astronomers, who now regard our solar system as derived from a relatively cool celestial body disrupted tidally by the close passage of a disturbing sphere, the meteorites that reach our earth being accepted as fragments of this disrupted body.

Effect of pressure on the disintegration of uranium.

Another speculation naturally follows. The disintegration of uranium with production of radium is an exothermic reaction accompanied by an increase in volume. Scientific investigators lay great stress upon the evolution of heat accompanying the subsequent disintegration of the radium and various deductions have been drawn on the assumption that depth will have no effect upon this process. After a study of such information as has been available to me in Calcutta, there seems to me to be no reason why, under a sufficiently high pressure, the disintegration of uranium should not be totally inhibited at a sufficient depth below the earth's surface, this supposition introducing the idea that it is possible by means of molar pressure to influence intra-atomic activity. That this possibility is almost a probability seems to follow from the work of Richards on the compressibility of elements, and the experiments and researches of Humphreys and Mohler upon the displacement of the spectral lines. The results of the latter experiments prove that the effect of pressure is to reduce the vibration frequency of the electronic corpuscles. If there be any foundation for this suggestion that at sufficiently great depths the disintegration of uranium may be inhibited by the combination of high pressure and temperature, then it is evident that speculations, such as those on the age of the earth, based upon the disintegration of radium, must be accepted with caution.

ON SOME OCCURRENCES OF WOLFRAMITE LODES AND DEPOSITS IN THE TAVOY DISTRICT OF LOWER BURMA. BY A. W. G. BLEECK, PH.D., F.G.S. (With Plates 1 and 2.)

INTRODUCTORY.

The field-work which furnished all data for this paper, was carried out during the months of August and September 1910. Only those who have passed through a rainy season in Lower Burma can appreciate the difficulties and discomforts of outdoor work during these months. In a sparsely populated country, where rest-houses are few and far between, and where roads are either non-existent, or in a very bad condition, where the jungle is practically impenetrable, and finally where the ordinary conveyances such as bullock-carts, boats and coolies are difficult to obtain, it was naturally impossible to go very far afield, and all geological work had to be restricted to observations along the line of march, and around the immediate neighbourhood of the various mining camps. I have come to the conclusion, however, that, although the geological mapping is very incomplete, the data collected for petrological purposes comprise practically everything of importance, as I shall show in the following.

A serious drawback to all geological and prospecting work in the Tavoy District is the absence of suitable topographical maps. The only available map is on the scale of 4 miles to the inch, and merely shows a few trigonometrical stations, the larger rivers and occasional villages and nothing else, in fact it is really a blank sheet showing a few fixed points. The map attached was plotted from a rough compass survey by Mr. Chater, A.I.M.M., and is sufficiently accurate for the present purpose.

The only important references to the petrology and to the occurrence of wolfram ores in the Tavoy District, will be found in the *Records* of the Geological Survey of India, Vol. XXVI, Pt. 3, 1893, Vol. XXXVIII, Pt. 1, 1909, and Vol. XXXIX, 1910.

GEOGRAPHY AND TOPOGRAPHY.

The Tavoy district in the Tenasserim division of Lower Burma is bounded to the south by the Mergui District, the southernmost district in Burma, on the east by Siam, on the west by the Bay of Bengal and on the north by the Amherst District. There are three main rivers in the district which are navigable for considerable distances by country boats and even by launches, *i.e.*, the Tavoy river and the Great and Lesser Tenasserim rivers. The Tavoy river flows into the sea at a distance of about 30 miles below the town of Tavoy. The great Tenasserim river flows south into the Mergui district, and the Lesser Tenasserim is one of its tributaries.

The town of Tavoy is the headquarters of the Tavoy district. The only other town of importance is Myitha, on the Lesser Tenasserim river or, as it is locally termed, the Ban River. Villages are few and far between and generally consist of half a dozen houses (more or less). Provisions are scarce and very difficult to obtain in these hamlets. The population consists chiefly of Burmese, with a few Chinese and natives of India.

With the exception of the flat land bordering the larger rivers and streams the country is very mountainous. The general strike of the ranges is N.NW.—S.SE. Elevations up to 6,000 ft. are recorded. For the most part the country is thickly jungle-clad, with high forest, and impenetrable undergrowth. Hill streams and torrents are innumerable and most of them carry perennial water. Narrow and deeply eroded valleys therefore form a main feature of the country.

The climate is by no means all that could be desired. The jungles are infested by mosquitos, sandflies, etc., and every precaution must be taken to guard against fever. The rainfall is a very heavy one, close upon 300 inches per annum, and most of this falls between the middle of April and the end of October.

GENERAL GEOLOGY.

Within the area shown on the map two distinct types of rock are found, *i.e.*, stratified rocks consisting mainly of quart-zites and schists, and intrusive rocks of acid types.

In the introductory part, I mentioned that the geological mapping had of necessity to be left very incomplete, and it therefore stands to reason that the stratigraphical and structural geology of the country still remains to be unravelled in detail. This will not be an easy task for two main reasons. In the first place outcrops, especially continuous outcrops, are, as far as I could judge, rare. This is due to the heavy forest growth. In the second place the nature of the stratified rocks does not lend itself readily to the drawing of conclusions of stratigraphical value over large areas, as the stratified rocks constantly change their texture and appearance chiefly owing to the varying degree of metamorphism which they have suffered from the contact with the intrusive rocks, and also owing to lateral variations in their primary sedimentary deposition. Thus I was not successful in locating any characteristic bed which could have served as a distinct geological horizon. To fix upon any sandstone or quartzite bed was out of the question, as neither texture nor colouring is sufficiently distinctive. There are several conglomerate beds, which might have been taken into consideration, but even these are of doubtful value for stratigraphical purposes for the above mentioned reasons. This also applies to the shales. There is, however, one characteristic bed of carbonaceous shale, which might answer the purpose. This shale, which is locally metamorphosed into a graphitic, chiastolite schist was found near the 11th milestone on the Tavoy-Myitha road, again almost opposite to Tavoy on the right bank of the river, again on the road from Shintabi to Pa chaung and again close to the mining camp near Kadwe. On comparing specimens from the different localities it was found, however, that the likeness was not very great, and no stratigraphical or structural conclusions could therefore be drawn.

Naturally no estimate can be made of the thickness of the whole ground of sedimentary beds until the structure has been unravelled. The dips of the stratified rocks throughout the area examined are to E., ENE. or ESE., at angles of 45° and steeper, the strike therefore being to N., NNW. or NNE.

Unconformities in the stratified rocks, as well as faults, may exist but could not be recorded. This is all I venture to say about the structure of the rocks.

The whole group of stratified rocks has been termed the Mergui series because they were first discovered in the Mergui district and thence traced into Tavoy. The geological age of these strata is uncertain. The Mergui series in Tavoy is quite unfossiliferous. The question of a possible correlation of these beds with others of known age, studied in other parts of Burma, may possibly be decided by a long campaign of field-work and would be of considerable scientific interest. For the purposes of the present discussion, however, this point is of no importance.

The second type of rock which occurs in the district examined is granite with all its various modifications, apophyses, etc. The granite is intrusive into the strata of the Mergui series and therefore younger than the latter. The intrusive granite has so altered the texture and mineral composition of the strata by contact-metamorphism, that their original appearance is completely changed.

It appears that the granite was intruded into the strata of the Mergui series during the time that the folding movements took place; it generally occurs in elongated bosses and very often forms the backbone of individual mountain ranges.

Both types of rock have their characteristic form of weathering. In the valley the granite weathers and decomposes into a coarse gravel consisting of the various mineral constituents of the rock. On the hill sides it shows smooth surfaces wherever the sides of the bosses are steep. An outward inclination of the natural division planes is distinctly noticeable, by reason of which the rock splits into large flat or rounded boulders.

The stratified rocks weather into a ferruginous earth, which, however, forms but a thin layer (a few feet) over the undecomposed rock. Undoubtedly the heavy rainfall of the country accounts for this thin covering of decomposition products. I may add that no laterite was met with. The rate and mode of decomposition, as well as the conditions of concentration of the mineral matter, are obviously not favourable for the formation of laterite.

Following the Myitha road from Tavoy I found continuous outcrops of stratified rocks of the Mergui series as far as the 18th mile. The road cuts across the strike of these strata and thus exposes a long section of these rocks. The quartz veins traversing the strata are very numerous and apparently all barren of ores of any description. Near the 18th mile granite was found *in situ* and with the exception of a small inlier of stratified rocks continues as far as the 22nd mile. The granite hills on the right banks of the Pauktaing chaung are capped by the stratified rocks.

On the right bank of the Tavoy river stratified rocks of the Mergui series were again met with practically opposite, and to the north of, the town of Tavoy. A few miles further south the hills are formed by bosses of granite.

On the road from Tavoy to Maumgmeshaung and thence on to the mining camps at Kadwe and Kadindo the strata of the Mergui series alone were found. Again these rocks are traversed by numerous quartz veins.

Following the route from the confluence of the Talaigna Chaung and the Tavoy river to Talaigna and across the Bolin taung (*taung* = hill) to the mining camp at Kalonta (No. 5) both granite and stratified rocks were encountered. The granite forms the eastern slope of the Bolin taung and crops out again in the valley near the mining camp.

On the right bank of the Talaigna chaung (river) rocks of the Mergui series border the narrow valley. Along the Kyauk chaung, however, as far as the mining camp on the Byauk chaung, huge granite bosses form the hills. Near the Byauk chaung mining camp (No. 3) strata of the Mergui series were found along the northern slopes of the hills.

On the road from Sintabi to the mining camp near Pa chaung (No. 1) the road reveals a series of outcrops of the stratified rocks. In the main range of hills to the west of Pa chaung a small outcrop of granite was discovered.

PETROLOGY AND MINERALOGY.

The Stratified Rocks of the Mergui Series.

Petrology and mineralogy.

The stratified rocks are divisible into two main groups, *viz.*, quartzites and schists. The occurrence is that of alternating beds, the quartzites predominating. These rocks have a distinctly stratified appearance and show good bedding planes.

The quartzites again can be subdivided into two classes, the sandstone quartzites and the conglomerate quartzites. The only difference between the two is that the conglomerate quartzite contains numerous rounded quartz pebbles as against the fine-grained, even appearance of the ordinary quartzites.

The colour of these rocks varies from a light grey to a light green. They have a distinctly vitreous appearance. For the most part they are very hard and break with a jagged splintery fracture, Near Pa chaung the quartzites have more the appearance of sandstones. These latter rocks have a fine-grained texture, are of a greyish brown colour, and lack the vitreous appearance and splintery fracture.

I now propose to give a description of a series of typical metamorphosed sedimentary rocks. The names of the places where they were found, and all the necessary details for record are also appended. Some hundred odd specimens of these rocks were examined microscopically. Of similar specimens from the same or adjoining localities the most typical have been chosen. For more convenient reference the specimens have been numbered.

A. *Specimens collected on the road from Tavoy to Wagon.*—A series of specimens taken from opposite the Pagaye bungalow ranging from ordinary quartzites to graphitic chiastolite schists :

1. a black graphitic schist, very friable, with an occasional thin hard band of black quartzite. Under the microscope a few clastic grains of quartz and sericitic matter were discernible. The greater part of the slide, however, was obscured by graphitic matter ;

2. this specimen was exactly similar to the one just described but showed one perfect cross section of an andalusite crystal ;

3. in another specimen of practically the same megascopic appearance as no. 1 the graphite was not so abundant and occurred in thin alternating bands together with sericite and chlorite. The quartz grains lie very close together and are cemented by a second generation of quartz and chalcedony ;

4. in another series of specimens of the black graphitic schists, as described in 1 to 3, and which occur interbedded with these, there are several thick beds of graphitic chiastolite-sillimanite schist. Both the chiastolite and andalusite are easily discernible megascopically as thin light-grey or white needles up to an inch in length and measuring one-twelfth of an inch in cross sections. Microscopically all these schists are in every way similar to those described in specimens 1 to 3. A few needles of sillimanite were also observed and an excellent basal section was obtained under the microscope, by which the sillimanite was easily identified. All these crystals of andalusite and sillimanite are ranged with their main axes parallel to the lines of stratification. I had a sample of this schist analysed for carbon contents, and the analysis gave a percentage of 2·9 carbon (sample dried at 100°C).

5. in other sections of specimens similar to No. 3 sillimanite was observed closely intermingled with the sericite and very twisted and bent, but the crystals were generally ranged with their long axes parallel to the bedding planes of the schists;

6. a series of schists directly in contact with those described in 1 to 5. These schists are harder and more gritty and become less and less graphitic, as they recede from the actual graphitic shales. They can generally be described as dark-grey, compact schists or as hard, light-grey schists. Microscopically they closely resemble the specimens, already described excepting that the andalusite disappears at once and the graphite gradually decreases in quantity, ultimately disappearing altogether, when the schists merely consists of sericite and of the two generations of silica, namely, the original clastic and fused grains and the subsequently infiltrated quartz and chalcedony. The latter often occur in distinct layers and give to the rock the megascopic appearance of a striated schist. Neither the quartz nor the aggregates of sericite and chlorite show any extraordinary megascopic features and therefore do not require special description.

This class of schist undoubtedly forms the transition series from schist to quartzite. The difference between the schist and the quartzites is really a very small one. The analyses of the schists as compared with those of the quartzites must of course be in accordance with the mineral composition as readily recognised microscopically and should therefore show but a slightly higher percentage of alumina than the quartzites. Another mineral that produces a schistose appearance is the graphite and in a lesser degree the andalusite and sillimanite. In the preponderance of their main constituents, however, and in the mode of occurrence of the clastic and secondary quartz and chalcedony, the schists and the quartzites are microscopically very much alike.

I now turn to a series of quartzites which, apart from the above schists, constitutes the greater part of the contact-metamorphosed clastic rocks between Pagaye and Wagon;

7. a light-grey, very friable rock resembling a very fine-grained sandstone. It often assumes a striated appearance resembling lines of stratification. Microscopic investigation shows that the rock consists of tiny fused quartz grains cemented by quartz and chalcedony. Thin layers of sericite and chlorite form regular bands within this quartz mass. The proportion of quartz to the other

minerals is about 9 to 1; no doubt the thin layers of sericite give the rock its banded appearance;

8. a very hard, dark-brown, grey or green rock of vitreous lustre sometimes resembling serpentine, more especially on the fresh splintery fracture. The microscope reveals the following mineral constituents: quartz, predominating, the single grains showing jagged edges; chalcedony forms the cementing material; sericite and radial chlorite aggregates, highly pleochroic (probably pennine), and a few crystals of iron pyrites were observed. In this species of rock quartz always largely predominates;

9. this is a very hard brown, grey or greenish rock of vitreous lustre and in every way, both megascopically and microscopically, similar to no. 8, excepting that it contains large rounded pebbles of quartz up to an inch or two inches in diameter;

10. another species of quartzite, which microscopically closely resembles no. 8, has a dark or light-grey and striated, banded appearance and is either very hard with a splintery and vitreous fracture or else has a more sandstone-like appearance. The striated appearance of the rock is caused by the chlorite and sericite minerals forming alternating layers with the quartz parallel to the stratification of the rock.

These different types of schist and quartzite show fairly uniform modes of weathering; but weathered rocks very often give the impression that a new type of rock has to be dealt with. A long series of such weathered rocks was examined microscopically, and it was always found that their mineral composition was exactly the same as that of types 1 to 10, as above described, excepting that they were more or less iron-stained. These rocks generally resemble a red, more or less friable sandstone or clayey shale. This is very noticeable on the road from Tavoy to Wagon. The colour of the road is red and a tough red mud is formed during the rains.

B. *Specimens collected on the road from Shintabi to Pa chaung.*—From a study of a collection of hand specimens from this locality it immediately becomes apparent that schists and even shales predominate over quartzites. The latter have more the appearance of sandstones. The mineral composition microscopically is almost identical with that of the specimens collected on the road from Tavoy to Wagon.

11. the first outcrops met with on the road from Shintabi to Pa chaung are dark-grey or black graphitic shales, containing also chiastolite and sillimanite. They are practically the same rocks as those described in nos. 1 to 5. The only slight difference worth mentioning is that the quartz is rather less predominant and the schistose structure, megascopically and microscopically, more pronounced;

12. a series of arenaceous schists of a dark or light grey colour, some slightly foliated, others with a silky sheen. Ten specimens collected all along the road were examined microscopically and it was found that their mineral constituents were almost identical. The proportion of quartz to sericite varied of course, but, generally speaking, these schists correspond very closely to the quartzites described under nos. 7 to 10. The primary quartz is generally finer grained. Pyrite was found in every slide. In the whole series of rocks rutile crystals are very common, the latter very often occurring as inclusions in the larger quartz grains;

13. a typical light-coloured sandstone, containing large nodules and layers of iron pyrites, and well stratified. It was found in the Nienni chaung. Microscopically it is identical with no. 8 or no. 9;

14. a brick-red shale with numerous white spots, evidently decomposed. It was found near the top lode on the Pa chaung range. The microscope reveals large grains of clastic quartz which form the white specks embedded in an indefinite, iron-stained groundmass.

The weathered types of all these rocks are identical with those described under nos. 1 to 10.

The metamorphosed sediments cropping out on the road from the camp on the Talaigna chaung to Byauk chaung are of a district type:

15. the schists found along the Chauk chaung near the Talaigna chaung are hard grey-green schists with black spots. Microscopically they consist of chlorite minerals (pennine), often in sphærulitic aggregates, and a few grains of quartz;

16. a second specimen from the same locality contains numerous crystals of ottrelite.

The schists on the Byauk chaung were too decomposed to allow of careful study. They were represented by brick-red ferruginous clay. The following are specimens of metamorphosed sediments found on the route from Talaigna across the Bolintaung to Kalonta;

17. a grey to green quartzite with a vitreous fracture similar in every respect to no. 8, found west of Bolintaung. The same kind of schistose quartzite often with a banded appearance, also occurs on the eastern slopes of the Bolintaung and along the eastern ridges of this hill. A little microscopic rutile was found in all these specimens.

Finally a series of metamorphosed rocks collected on the road from Maungmechaung to Thangazon and from the Kadwe and Kadindo ranges was examined. Every kind of schist, graphite schist, chiastolite schist, etc., and quartzite as described under nos. 1 to 10 was met with, but no other types whatsoever of the Mergui series of rocks were discovered.

The appearance and peculiarities of the decomposed rocks of the Mergui series have already been described in a previous short paragraph for one special group nos. 1 to 10. This description applies to all the metamorphosed sediments.

It is of course obvious that the 17 specimens above described do not represent 17 defferent species of metamorphosed sediments. The description was deemed necessary to emphasize the likeness of the various specimens collected from different localities.

There are two minerals of special interest, one of which has not been mentioned, namely, tourmaline and andalusite. The former was observed microscopically in almost every slide. Both minerals are typical of contact metamorphism. It has already been pointed out that the granite has altered all sedimentary rocks through contact metamorphism. Both the presence of tourmaline and of andalusite confirm this. Moreover, the andalusite points to metamorphism under comparatively low pressures, this mineral being the member of the Al_2SiO_5 group with the smallest specific gravity.

In the foregoing, the rocks of the Mergui series have always been described as metamorphosed sediments. It would be of some interest to trace back the original appearance and composition of these sediments. The graphitic shales were originally, before metamorphism, undoubtedly ordinary shales having a mineral composition in which clastic quartz predominated with aluminous silicates and carbonaceous or other organic matter. The quartz remains, the aluminous silicates are represented in the metamorphosed rocks as sericite and chlorite, the latter being the metamorphosed product of any ferro-magnesian clastic material, whilst the organic matter is turned into graphite. The andalusite is in all probability derived from hydroxides of aluminium, which always exist in sedimentary rocks, together with free silica. Infiltrated silica forms the cementing material, which appears as secondary quartz and chalcedony.

The quartzites are undoubtedly the metamorphosed products of conglomerates, sandstones, more or less argillaceous, and arenaceous shales. Their outward appearance suggests this in the first place. In the second place, their mineral composition and micro-structure is a definite proof. Infiltration of silica filled up the interstices of the sandstone and made the rock compact. The micaceous matter was probably an ordinary constituent of the sandstone or was formed by sericitisation of clastic felspar, whereas the chlorites were derived from the clastic ferro-magnesian silicates.

Most of the tourmaline and some rutile are entirely new constituents of these metamorphics, and have been introduced by pneumatolitic processes from the intrusive granite.

The great similarity between all the specimens of metamorphic rocks collected from different localities and representative of a large area topographically, proves not only that the form of metamorphism must have been identical everywhere, but that the sedimentary rocks themselves must have been represented by a very uniform series of shales, sandstones and conglomerates. This of course is a general statement and made without prejudice to the fact that the effects of contact metamorphism are less pronounced in some localities than in others, and also without prejudice to possible lateral variation of the sediments.

The Igneous Rocks.

These rocks are all of acid type and are mostly granites. Specimens intended for microscopic examination were only collected wherever the granite was in direct contact with the wolfram lodes. Thus the granite which occurs near Pa chaung, on the Talaigna and Byauk chaung as well as on the Kadwe and Kadindo ranges, was not examined microscopically. These latter granite occurrences all show an ordinary holocrystalline structure and appear to be the ordinary form of biotite granite. The following is a description of a series of granite specimens collected in the vicinity of the 21st mile on the Tavoy-Wagon road:

18. an ordinary light-grey biotite granite of the usual holocrystalline structure. In some places it becomes coarser-grained and of pegmatitic appearance. Microscopically it was found to contain quartz with minute liquid inclusions, also orthoclase with liquid inclusions as well as inclusions of rutile and plagioclase, determined as oligoclase-andesine, with tiny inclusions of biotite. The following is a complete analysis of this granite :—[1]

SiO_2	74·65
Al_2O_3	13·48
Fe_2O_3	0·07
FeO	0·89
SnO_2	none.
MgO	0·38
CaO	0·15
Na_2O	4·93
K_2O	4·65
TiO_2	trace
P_2O_5	0·03
MnO	0·25
H_2O	0·55
(Sample dried at 100°C.)	100·03

19. Granite-porphyry. Large phenocrysts give this granite its porphyritic appearance. The plagioclase was again determined as oligoclase-andesine. The individual crystals contain numerous vesicular inclusions in their centre and often show the initial stages of sericitisation. Accessories such as rutile, zircon and perowskite were detected in various slides. A partial analysis[2] of this granite showed the following proportions of silica, lime, magnesia, soda and potash and some accessory cassiterite :—

	Per cent.
Silica	74·51
Lime	2·61
Magnesia	0·21
Soda	5·99
Potash	2·61
Tin	0·15
(Sample dried at 100°C)	..

[1] Analysis by C. S. Fawcitt, F.C.S.
[2] By C. S. Fawcitt, F.C.S.

Tin-stone as an accessory is interesting and will be referred to in a later paragraph.

These are the two typical granite types from the vicinity of the 21st mile on the Wagon road. Aplitic or pegmatitic apophyses were not observed, although this does not imply that they do not exist.

A second series of granite specimens examined is that of the Bolintaung, near the Kalonta concession:

20. a fine-grained, very light, grey-green granite from the Bolintaung. Plagioclase appears to be entirely absent. Besides felsoer, the predominating minerals are biotite and muscovite. Tourmaline and zircon are the accessories;

21. a very fine-grained, light-coloured granite. Microscopic examination shows preponderating plagioclase (oligoclase and albite), orthoclase, quartz and biotite. The individual plagioclase crystals are usually large;

22. a granite similar in appearance to no. 21, but showing less plagioclase. Muscovite again appears; rutile and very little tinstone are the accessories.

The following is an analysis[1] of granite no. 21:—

	Per cent.
SiO_2	78·14
Al_2O_3	12·54
Fe_2O_3	0·12
FeO	0·86
BiO_3	0·03
SnO_2	*nil*
CaO	0·44
MgO	0·12
K_2O	3·20
Na_2O	3·79
MnO	0·12
MoO_3	0·09
P_2O_5	trace
H_2O	0·46
	99·91
W, Ti, S	*nil*

(Sample dried at 100° C).

[1] By C. S. Fawcitt, F. C. S.

23. A greyish-green, very fine-grained rock resembling the quartzites, but without their splintery and vitreous fracture. It is composed chiefly of ordinary amphibole (green and slightly pleochroic) and sphærulitic chlorite, some plagioclase, in advanced stages of alteration into zoisite, and also some quartz. This rock was found in contact with the true quartzites and close to the granite. It was impossible to determine whether it occurred as a vein in the quartzite or as a contact rock between the granite and the quartzites. A specimen was collected on the western slope of Bolintaung.

The form of weathering of the granite has already been mentioned. Distinct directions of fissuring were observed, more especially in the granite occurring between the Talaigna and Byauk chaungs. The directions were NW and NNE; the fissures were filled with quartz.

It has already been pointed out that the metamorphism of the stratified rocks is true contact-metamorphism brought about by the above igneous rocks. It is quite impossible to estimate the width of the contact zone from any special observed occurrence of granite or to form any estimate of the intensity of the metamorphic action. The only other point of interest is that the granite becomes in many places porphyritic when in contact with the sedimentary rocks. The reason for this porphyritic structure is probably explained in quite a simple way. Where the granite-magma came into contact with the porous sandstones (now metamorphosed into quartzites) it must have lost a large proportion of its magmatic waters. These waters no doubt were the main metamorphic agents in the sedimentaries. The loss of this magmatic water must have increased the viscosity of that part of the magma which was in contact with the sandstones. The higher viscosity near the contact then influenced the resulting crystals with regard to the order of their crystallisation. In this order of crystallisation the accessories and micas may be neglected as their crystallisation velocity in all probability makes their crystallisation independent of the gradually increasing viscosity. The first mineral to be affected is the plagioclase as it crystallises more slowly and yet earlier than the orthoclase and quartz,—this on account of its higher melting point. Thus the plagioclase would grow and form phenocrysts, displacing the more slowly growing crystals of quartz and orthoclase. The comparatively high percentage of soda shown in the second analysis also points to predominating plagioclase. Evidently the plagioclase was an excess component above the eutectic composition of the "contact magma" and therefore had to separate first. The growth of these plagioclase phenocrysts then continued until the eutectic point had been reached for the remaining components of the magma, from which point onwards these latter crystallised in their normal order, as they appear in the ordinary granite. This point was evidently reached before all the plagioclase had crystallised, as there are still numerous crystals of plagioclase which show no signs of zonal growth, although all the phenocrysts do. The partial analysis (no. 2) does not show any unusually high percentage of silica nor do any new minerals appear in the slides which might point to any resorption of new mineral matter from the contact sediments.

The Mineral Veins and Lodes.

For the purpose of their mineralogical and petrological discussion no distinction can be drawn between ore-bearing lodes and barren quartz veins since I regard the ores simply as local accessories of the quartz veins. It should of course be mentioned that some barren quartz veins are of secondary, that is, non-igneous origin; these are excluded from this discussion; it would be difficult to distinguish them from the primary and igneous veins and they will probably be of very minor importance.

Quartz veins are very numerous throughout the country examined. They vary in width from a fraction of an inch to 12 feet and more in thickness. The thickness of each individual vein varies again along the strike and to the dip.

A large number of quartz veins was observed in the granite along the 21st mile on the Tavoy-Wagon road. Here they are more frequent near the outer margin of the granite and near the contact with the metamorphic rocks. The veins stand almost vertical and appear to dip in towards the centre of the granite boss. The road opens out a section through the metamorphic rocks, the granite and the mineral veins.

In the granite-mass between the Talaigna chaung and the Byauk chaung the quartz veins strike in the same direction as the main fissures of the granite, *viz.*, NW and NNE. Nothing definite can be said about the varying thickness and the continuity of the lodes within the granite zone. The lodes were evidently formed in irregular contraction fissures near the outer margin of the granite. Individual veins, each one continuously varying in thickness, have been traced for considerable distances (a quarter of a mile or more) in the granite, but only along the strike. Nothing as yet is known of the conditions to the dip.

The main strike of the quartz veins in the metamorphic rocks either corresponds to the strike of the country or runs at almost right angles to this strike. In connection with this it can be clearly observed that the veins following the bedding-planes of the metamorphic rocks are generally of a very uniform thickness and structure over long distances, whereas the veins crossing the bedding-planes of the metamorphic rocks are not at all uniform in thickness or persistent in their length of strike. These latter have been split up into numerous little leader-veins and constantly separate and unite again. The re-union of these lodes is very often brought about by the tendency of the separate leaders to follow some distinct bedding-plane in the metamorphic rocks but, owing to the continuous separation, the original lode soon disappears entirely along the strike.

As the quartz veins stand the weathering very much better than the country-rock, they generally stand out prominently and can easily be traced over the hill-sides. Wherever they break up, numerous irregular pieces of quartz are strewn over the ground.

The walls of the quartz veins in the granite are usually distinct so that the lode parts easily from the country. On the other hand it has been observed in a very few places, usually in the granite, that the veins were frozen to the "country." "Horses" of granite within the lodes are fairly frequent, this granite being of an altered appearance and containing a great deal of chlorite along the contact borders. A concentration of micaceous minerals in the country-rock and along the contact walls of the veins is very common.

The walls of the veins within the metamorphic rocks are always distinct.

Faults were not observed, but they will probably be discovered where the veins occur in the metamorphic rocks, since considerable orogenic movements in the metamorphics must have taken place over long periods of time in consequence of the extensive intrusions of the igneous rocks, and after the cessation of the post-volcanic activity as evidenced by the mineral veins and lodes.

According to their mineral contents the lodes of the Tavoy district, so far as I was able to visit them, can be divided into three subdivisions having regard to the ore-contents of the lodes :—

1st, the wolframite-quartz lodes ;
2nd, the cassiterite-quartz lodes ; and
3rd, the wolframite greisen.

The wolframite-quartz lodes are the most important of this group. Of the other two lodes only one of each was observed. They will be treated separately at the end of this section.

The wolframite occurs in scattered and irregular patches in a white opaque mass of quartz. Single crystals of wolframite up to 3 and 4 inches in length, as well as large masses of crystal aggregates weighing up to 90 lbs., are sometimes found, forming the visible ore of the lodes. On those lodes, which have been proved to be ore-bearing, long stretches apparently carry no wolfram values whatsoever. Then again the quartz is studded with single wolframite crystals, or aggregates of such crystals, for considerable distances. It is thus impossible to estimate, even approximately, the ore contents of any of these lodes. In order to arrive at the percentage of wolframite in the lode, bulk-sampling on a large scale would have to be carried out. I have already mentioned that a large number of barren quartz veins were observed. The quartz of these veins is very similar in appearance to that of the wolframite-quartz veins. Considering the erratic occurrence of the wolframite in the lodes, I am of opinion that these barren quartz veins are in some part or another ore-bearing, and that in all probability one and the same lode may carry wolframite values for a short distance and then run into a perfectly barren quartz lode which may continue barren for considerable distances. The relationship between the wolframite-quartz lodes and the barren quartz lodes has yet to be established, but when lode-mining is seriously undertaken it would be of considerable importance to follow the outcrop of a wolframite-quartz lode or as many of these lodes as is possible, merely to ascertain whether a wolframite-quartz lode is ore-bearing throughout or whether it may run into an absolutely barren quartz lode.

At the present stage of exploitation nothing can be said with regard to the relationship of roe contents of the lode to the country rock. The lodes are alike in appearance, both in the granite and in the metamorphic rocks.

Equally there are no data available as to whether the lodes increase or decrease in richness at depth. Wolframite lodes, needless to say, can never show any secondary enrichment.

A distinct relationship exists between the richness of lodes and the strike of the lodes. Lodes running against the general strike-direction of the metamorphic rocks are apparently richer than lodes following the strike-direction and this more especially, wherever the lode changes its direction of strike. Observations of this kind were made at Kadwe.

The following are the individual minerals which were observed in the lodes :—

Quartz.—This mineral forms the gangue of the lode. It is of a milky white and very compact appearance and has a vitreous lustre on the fractured surfaces. In some localities it is honeycombed and iron-stained along the outcrops, notably at Kadwe. This honeycombed appearance is probably due to the decomposition of sulphides in the lode. Very often the quartz shows numerous little cracks and veinlets containing red oxide of iron. Microscopically the quartz generally contains numerous vesicular inclusions. The extinction is undulatory. A large number of specimens from different lodes and localities were examined and everywhere the quartz showed the same appearance and properties.

Wolframite and *tungsten ochre* are the only wolframite ores of any economic value found in the lodes.

A typical variety of the wolframite contains about 76 per cent. of tungsten trioxide. The colour of the mineral is dark, iron or reddish-black. The crystals are monoclinic. The specific gravity is nearly 7·3. Tungstite (yellow ochre of tungsten) is found in very small quantities together with wolframite and very often forms a thin yellow coating over that mineral. Tungstite is undoubtedly a product of decomposition of the wolframite. The latter ore is found both massive and in crystals or aggregates of crystals. On several good wolframite crystals from Tavoy, I have observed crystal faces with longitudinal striations, orthopinacoids terminated by orthodomes.

Mica.—Four distinct members of the mica division occur in the lodes. The size of a single flake of any of them is small, generally under one-eighth of an inch in diameter. They occur in single flakes and in aggregates of crystals. The commonest variety is muscovite, of which small colourless or yellow flakes occur

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2 (free)	66·15	76·40	96·55	84·49	85·89
" (combined)	..	..	..	..	0·83
Fe_2O_3	0·92	0·19	0·54	0·54	0·91
FeO	2·95	4·00	0·28	1·44	1·15
Al_2O_3	2·75	1·65	0·85	0·78	5·75
PbO, CuO	..	..	0·04	..	0·07
BiO_2	0·03	0·07	0·23	trace	..
SnO_2	trace	..	..	0·75	..
MnO	0·35	0·45	0·15	2·02	0·42
BaO	..	..	..	0·03	0·05
CaO	1·65	0·32	0·45	0·41	0·26
MgO	0·07	0·13	0·13	0·08	0·18
K_2O	..	0·21	trace	0·20	1·20
Na_2O	..	0·25	trace	0·29	0·65
As_2O_3	..	..	trace	..	..
MoO_3	0·14	0·03	0·58	0·12	0·57
WO_3	12·32	14·35	..	8·57	..
Cb_2O_5	11·58	1·33	..	0·30	..
P_2O_5	0·06	0·05	0·06	..	trace
CO_2	0·45	..	..	..	..
S	trace	trace	0·03	trace	..
F	..	..	..	..	..
H_2O	0·52	0·33	0·06	0·15	0·80
	99·94	99·76	99·95	100·17	99·86
				Samples dried	

TABLE 1.—*Analyses of*

(Analyses made by C. S.

No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
69·23	73·05	52·40	97·90	90·05	58·80	16·85	0·23	0·30
13·97	..	..	..	..	..	..	..	..
0·37	1·07	31·77	0·25	3·88	2·71	..	..	..
2·40	3·00	1·15	0·22	1·22	6·01	11·37	13·24	13·80
7·11	1·13	2·87	0·47	2·96	2·27	1·24	0·85	0·81
..	trace	0·03	0·63	..	0·02	0·01	..	..
0·05	0·17	0·53	0·03	0·07	0·19	0·20	1·02	0·14
..	..	..	..	..	..	trace	trace	trace
0·52	5·60	1·65	0·11	0·04	..	7·74	9·43	9·36
..	..	..	..	..	..	..	..	..
0·20	0·17	0·25	0·07	0·24	0·48	..	trace	trace
0·12	0·07	0·32	0·05	0·16	0·25	trace	trace	trace
1·16	0·15	0·33	trace	0·18	0·25	trace	..	..
1·91	0·18	0·40	trace	0·22	0·30	..	..	..
trace	trace	trace	..	..	..	..	..	..
0·11	0·50	0·12	0·03	0·05	0·56	1·45	1·37	0·51
1·99	14·10	1·90	..	..	24·45	61·00	74·09	74·78
0·34	0·72	..	..	..	2·33	0·30	0·53	0·29
trace	trace	..	0·05	0·03	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	..	0·11	..	..	..	..	..
0·02	..	..	..	..	..	..	..	..
0·40	0·25	6·55	0·02	0·64	1·55	0·25	0·19	0·22
99·90	100·26	100·27	99·94	99·74	100·17	100·11	99·95	100·13
at 100° C.								

wolframite lodes.

Fawcitt, F.C.S.)

throughout the lodes. In some lodes lithia-chlorite was observed. This is yellowish brown; the lithia can only be detected chemically. A third member of the mica division which occurs very frequently on all the lodes is the ordinary green chlorite. Microscopically this chlorite was determined as pennine.

The following minerals have been observed in all the lodes, but in negligible quantities :—molybdenite, bismutite, iron pyrites, copper pyrites, galena and mispickle. Columbite, in black orthorhombic crystals, was observed in all the lodes. Tourmaline is present everywhere, generally in microscopic crystals.

Cassiterite is very rare in the wolframite-quartz lodes, in all the localities examined by myself. But at Hermyingyi and several other localities, it is said to be an important ore in the lodes.

The analyses of a series of lode specimens, printed on pages 66 and 67, corroborate generally the megascopic and microscopic investigations of the mineral contents of the lodes. Analyses 1, 2 and 3 are of lode specimens from the 19th mile on the Tavoy-Wagon road; analyses 4 and 5 of lode specimens from Kalonta; analyses 6 and 7 of lode specimens from Pa chaung; analyses 8 and 9 of lode specimens from Thangazon; analyses 10 and 11 of lode specimens from Byauk chaung; analysis 12 represents a specimen of ore concentrates; analyses 13 and 14 represent practically pure wolframite.

The mineral paragenesis of the wolframite lodes within the areas visited becomes apparent from the above. It is worthy of notice that no fluorspar was found anywhere. A distinct feature of all these lodes is the predominance of wolframite over all other minerals, excepting quartz; all the other minerals occurring as accessories and in practically negligible quantities.

I have already mentioned that a cassiterite-quartz lode was found and should be classed as a distinct lode. It was found in the Kalonta area. Analyses of two specimens from this lode are given in Table 2.

The tin occurs in the same irregular way as the wolframite. The colour of the mineral is brown to reddish-brown and it occurs both in square prisms and in orthohedra. The grains very seldom exceed $\frac{1}{4}$ inch in diameter. The lode appears to be a very narrow one, about a foot in thickness, and carries cassiterite values, wherever observed. Wolframite appears to be entirely absent from this lode. The tin lode occurs in close proximity to a wolframite

	No. 1.	No. 2.
	Per cent.	Per cent.
SiO_2	84·00	97·18
Fe_2O_3	0·43	0·08
FeO	0·55	0·45
Al_2O_3	0·95	0·02
CuO, PbO, BiO_3	..	trace
SnO_2	13·95	2·30
MnO	0·08	trace
CaO	0·03 }	trace
MgO	0·01 }	
K_2O, Na_2O	trace	..
MoO_3	trace	0·02
P_2O_5	0·03	..
H_2O	0·12	..
Samples dried at 100° C.	100·15	100·05

TABLE 2.—*Analyses of specimens of cassiterite-quartz lode of Kalonta.*
(Analyses made by C. S. Fawcitt, F.C.S.)

lode and was apparently formed in a re-opening fissure of the latter; the parting between the lodes, however, is very distinct.

Tin is also known to occur as an accessory mineral in the granite and frequently, when cassiterite makes its appearance in any quantity in the float, it has been derived either from the granite or from a separate quartz cassiterite lode.

A third type of lode was observed at Kalonta. This was composed of quartz, muscovite and wolframite. It was observed *in situ* close to the quartz-tin and quartz-wolframite lodes. In this lode the quartz is of the usual granitic type, that is to say, it forms with the mica a rock having the appearance of an intrusive dyke and may be classed as a greisen. The micas show a lithia reaction. Wolframite occurs in small crystals scattered throughout this rock. Tourmaline is an accessory of this greisen.

Genesis of the lodes.—It has already been suggested that the mode of occurrence, etc., pointed to an igneous origin for the lodes. Geologically these lodes constitute evidence of post-volcanic activity following upon the intrusion of the granite magma into the sedimentaries of the Mergui series.

It is abundantly clear that the post-volcanic activity continued long after the solidification of the granite. This is evidenced by the granite "horses," which occur in the ore-lodes and which were evidently torn away from the granite walls owing to the force with which the lode-matter entered the fissures.

In a general way it may be taken that the lodes were formed in the following manner: the effusion of the granite magma forced its way towards the surface, thereby displacing and fracturing the sedimentary rocks. As it solidified crevices were formed, through which the mineral solutions found their passage, ultimately depositing their load of mineral matter not only in the fissures in the granite but also in the "country" rock. The force of these circulating solutions, which was undoubtedly enhanced by continuous orogenic movements, opened out new channels in the country rock, such channels generally following the line of least resistance, *i.e.*, the bedding-planes of the metamorphic rocks. Thus I would suggest the reconstruction of the purely mechanical process of lode-genesis in the Tavoy district.

Judging by the petrological and chemical evidence detailed above, there appears to be little doubt that the ore-lodes of the Tavoy district indicate a distinct "mineral zone," this term being used in a parallel sense to that of petrological province. This mineral zone is characterised by the persistent occurrence of the mineral columbite. In other parts of the district, which were not visited by me, tin ores perhaps predominate over wolfram ores, and in a broader sense and applied over larger areas, the mineral zone might be termed a wolframite-cassiterite-columbite zone.

It may be assumed that the granite magma contained all the elements of wolframite, cassiterite, columbite and the other ores. It may also be assumed that locally the magma was richer in wolfram than in tin, etc. Thus the local preponderance of wolframite over cassiterite could primarily be explained.

After the igneous effusion had taken place, but when the magma was still unconsolidated, differentiation took place, whereby the heavy metals together with some mother liquor were separated from the quartz-felspar-micamagma. Thus it would appear that numerous and distinct centres of differentiation were formed within the cooling mass. From these centres the contraction fissures were injected with the gangue and ore which forms the lodes. Only thus it is possible satisfactorily to account for the phenomenon that there appears to be no communication between the different centres of lode-origin. If such a theory be accepted it is obvious that any speculations as to the continuation of lodes to depth within the granite are futile.

This theory of local differentiation may also explain the occurrence of separate cassiterite-quartz lodes, as it is quite possible that the differentiation in respect of the different metals took place at different times after the magmatic effusion. This might lead to the formation of cassiterite lode-centres quite distinct from the wolframite lode-centres.

That aqueous solutions were responsible for the formation of the wolframite lodes seems abundantly clear, if only from the one fact that the gangue quartz is crammed with liquid inclusions. At the same time the pneumatolitic process of mineral formation went on side by side with the deposition of lode-matter from solutions and was responsible not only for the tourmalinisation of the country rock and of the lodes, but also for the occurrence of such minerals as molybdenite and some of the micas.

In some cases the mother liquor which had become differentiated from the granite magma may have been injected into fissures in a magmatic state and not in the form of aqueous solutions. Such instances may have given rise to the formation of wolframite greisen.

The origin of cassiterite as an accessory of the granite has, wherever observed in other parts of the world, generally been attributed to pneumatolitic processes. Such volatile compounds of heavy metals often tend to collect at the margins of the intrusions and it is actually round the margins of the granite that the cassiterite occurs most frequently as an accessory mineral. Naturally this pneumatolitic process is not exclusive and need in no way clash either chemically or physically with the theory of lode-formation from magmatic injections or aqueous solutions, as outlined above.

No doubt the decrease of temperature and pressure, which stand in intimate connection with the distance from the intrusive granite, had a considerable influence on the deposition of ore within the lodes. Possibly the gradual change from ore-quartz vein to barren quartz vein was due to some such cause.

Float deposits—Of considerable importance from an economic point of view are the workable float deposits which are found in close proximity to the lodes. The disintegration of the wolframite lodes have led to the formation of ore concentrates constituting workable deposits.

The topographical features are of the greatest importance in locating these float deposits. I have mentioned above that most of the lodes occur near the crests of the hill ranges and practically form the backbones of those hills. Numerous little streamlets originate high up on the hill-sides. These small streams carry the disintegrated material from the lodes down the hills and into the main valleys. One therefore expects to find the first concentration of ore in and alongside the beds of these little streamlets and a further concentration in the main valleys. Between the feeder streams, however, and down the hill-sides, no concentration of float can be expected.

The thickness of the alluvial deposits varies considerably. Down the hill-sides, and more especially in the beds of the streamlets, only a very small thickness of float can be expected, varying from a few inches to perhaps 2 or 3 feet according to the steepness of the hills and the fall of the streams. In the valleys, however, the thickness of the alluvial deposits is very much more considerable. Here it again depends on the fall of the main stream and on the width of the valley, but generally speaking the float deposits in the main valleys are several feet in thickness. As may be expected the material of these float deposits in all the narrow valleys and down the hill-sides is very little water-worn, this being more especially the case near the heads of the streams.

Wolframite and cassiterite, by reason of their high specific gravity, are never carried far from the lodes. The richest concentration will therefore be in the valleys immediately beneath the disintegrated lodes. The wolframite breaks up very easily and is generally found in small prisms varying in size from dust up to half an inch in length. In close proximity to the lodes the float ore generally consists of wolframite or cassiterite still surrounded by gangue-quartz.

I have already pointed out that cassiterite generally occurs in negligible quantities in the wolframite-quartz lodes. Therefore it is only reasonable to believe that, wherever cassiterite is found in large quantities in the alluvium, it was derived from a separate cassiterite-quartz lode or else originated from the granite, of which it very often forms a constituent and accessory mineral, and only in a few instances from mixed wolframite-cassiterite lodes. Cassiterite in the float deposits will therefore always be expected, wherever the tungsten lodes occur in the granite. Where, however, the float deposits are found within the zone of metamorphic rocks, tin, if found in large quantities in this float, will frequently have originated from separate cassiterite-quartz lodes, as for instance, at Kalonta. The Kalonta float carries a large percentage of cassiterite, and this float has been worked by the natives for tin. In this case the primary origin of the cassiterite is beyond doubt a well-defined cassiterite-quartz lode.

Generally speaking there are three different kinds of float deposits. The first is the float deposit within the granite country. In the granite hills the valleys are generally much steeper and narrower than in the metamorphic areas. The float deposits therefore generally consist of large granite boulders together with the lode-float. The thickness of the float deposits is very inconsiderable and the float ore is often carried a considerable distance away from the lode. The second kind of float deposit is characterised by large and small boulders of hard quartzites, in which the pure wolframite or quartz wolframite boulders are embedded. In this kind of deposit the wash is loose and the ore easily won. A third kind of float deposit generally occurs in the softer metamorphic rocks. On disintegration these latter form a sticky clay in which the wolframite float becomes embedded. The ore from these float deposits is not so easily won, since the clay requires a great deal of puddling.

MISCELLANEOUS NOTES.

Correction in Generic Nomenclature of Bugti Fossil Mammals.

Amongst Mr. C. Forster Cooper's collections from the Gaj bone beds of the Bugti hills during the cold weather of 1910-11 is a lower carnassial of an *Amphicyon*, in a perfect state of preservation. I am indebted to Mr. Forster Cooper's kindness for a plaster cast of this specimen and for permission to write this note. I found on comparing the cast with the lower carnassial of the mandible described by me under the name of *Cephalogale shahbazi*,[1] that the two undoubtedly belonged to the same species, although the badly mutilated condition of my specimen produced an entirely false impression of the structure of the tooth and would not allow me at that time to refer it to *Amphicyon*. It also seems not unlikely that the upper molar described in the same memoir under the name *Amphicyon* sp. cf. *major* Blainv.[2] belongs to the same species as the mandibles. I have carefully compared the cast of Mr. Forster Cooper's specimen with the corresponding tooth in *Amphicyon giganteus* Laurillard from the Sables d'Orleanais and *Amphicyon major* Blainville from Sansan, and find that the Bugti specimen is undoubtedly distinct from either of these, and is therefore entitled to rank as a distinct species, to which the name *shahbazi* has already been applied.

During a recent visit to Basle, Dr. H. G. Stehlin suggested to me the possibility that the fragmentary maxilla containing the last premolar and the first molar, described and figured by me under the name of *Palæochærus affinis*[3] should rather be referred to the bunodont form of *Listriodon*. A comparison of the Bugti specimen with casts of the European species *Listriodon lockharti*, from the burdigalian, kindly sent to me by Dr. Stehlin, has convinced me of the correctness of this reference. The distinctive characters of the last premolar in the Bugti specimen, which ally it to *Listriodon* rather than to *Palæochærus*, *Hyotherium* or *Sus*, are (1) the strength and peculiar shape of the external cingulum and (2) the anterior position of the main inner cusp. Its differences from *Listriodon lockharti* consist in (1) its

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[1] The Vertebrate Fauna of the Gaj Series in the Bugti Hills and the Punjab, *Pal. Ind.*, New Series, vol. IV, pt. 12, Pl. III, figs. 12, 2.

[2] *ibid*, p. 10, Pl. I, fig. 4.

[3] *ibid*, p. 37, Pl. XII, fig. 7.

inferior size, (2) the more marked separation of the two main cusps, the ridge uniting them being even less noticeable than is the case in *Listriodon lockharti.* The same is true of the first molar, though shown less clearly on account of its more advanced wear. The Bugti species in fact shows less tendency to lophodonty than the European and approaches more nearly to *Sus* and *Hyotherium.* It is, therefore, quite entitled to specific distinction under the name of *Listriodon affinis.*

[G. E. PILGRIM.]

A. W. G. Bleeck Photo. *G. S. I. Calcutta.*

CASSITERITE-WOLFRAMITE LODE.

Hermyngyi, Tavoy

CALCUTTA
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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1913. [July

THE MINERAL PRODUCTION OF INDIA DURING 1912. BY H. H. HAYDEN, C.I.E., F.G.S., *Director, Geological Survey of India.*

CONTENTS.

I—INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII), although admittedly not entirely satisfactory, is still the best that can be devised under present circumstances. The methods of collecting the returns are becoming more precise every year and the machinery employed for the purpose more efficient. Hence the number of minerals included in Class I—for which approximately trustworthy annual returns are available—is gradually increasing and it is hoped that before long the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will be reduced to a very small number. In the case of minerals, such as tin-ore, still exploited chiefly under primitive native methods and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible, but the total error from year to year is not improbably approximately constant and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small native alluvial industry contributes such an insignificant portion to the total outturn that any error from this source may be regarded as negligible.

Total value of production.

Table 1 shows the values of the production of minerals for which returns are obtainable. It has not been customary hitherto to include in this table such materials as building stones, road metal and clay, since the returns are incomplete. To omit them altogether, however, is even more misleading than to include the returns in their imperfect state, and as the value is not inconsiderable, the figures have been added to the table; they probably represent less than half the actual production of those materials.

TABLE 1.—*Total value of Minerals for which Returns of Production are available for the years 1911 and 1912.*

—	1911.	1912.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Coal	2,502,616	3,310,365	807,749	..	+ 32·3
Gold	2,238,143	2,271,806	33,663	..	+ 1·5
Petroleum	884,398	975,278	90,880	..	+ 10·3
Manganese-ore (*a*)	648,801	884,404	235,603	..	+ 36·3
Salt (*b*)	469,235	509,824	40,589	..	+ 8·6
Mica (*c*)	188,642	284,290	95,648	..	+ 50·7
Building materials and road metal.	246,446	270,980	24,534	..	+ 10

(*a*) Value f. o. b. at Indian Ports.
(*b*) Prices without duty.
(*c*) Export values.

TABLE 1.—*Total value of Minerals for which Returns of Production are available for the years 1911 and 1912*—contd.

——	1911.	1912.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Saltpetre	220,268	217,035	..	3,233	— 1·5
Lead-ore and Lead	181,989	153,069	..	28,920	— 15·9
Tungsten-ore	99,989	115,200	15,211	..	+ 15·2
Ruby, Sapphire and Spinel.	67,594	69,547	1,953	..	+ 2·9
Clay	66,207	66,187	..	20	..
Iron-ore (*d*)	34,496	47,044	12,548	..	+ 36·4
Tin-ore and Tin	24,931	50,944	26,013	..	+ 104·3
Monazite	24,044	41,419	17,375	..	+ 72·4
Copper-ore	3,404	13,709	10,305	..	+ 302·7
Silver	11,575	11,829	254	..	+ 2·2
Jadestone (*c*)	41,660	10,800	..	30,860	— 74·1
Magnesite	1,047	4,614	3,567	..	+ 340·7
Chromite	5,072	3,849	..	1,223	— 24·1
Alum	2,819	2,627	..	192	— 6·8
Steatite	1,225	1,429	204	..	+ 16·6
Corundum	1,725	1,295	..	430	— 24·9
Garnet	2,126	1,176	..	950	— 44·7
Gypsum	2,308	1,032	..	1,276	— 55·3
Bauxite	5	516	511	..	..
Diamond	478	411	..	67	— 14
Paltinum	244	386	142	..	+ 58·2
Amber	133	179	46	..	+ 34·6
Ochre	34	161	127	..	+ 374
Samarskite	89	81	..	8	— 9
Graphite	9,425	*Nil*	..	9,425	..
Total	7,981,168	9,321,486	1,416,922	76,604	+ 16·8
			+£1,340,318		

(*d*) For provinces other than Bengal, Bihar and Orissa values estimated approximately.

It is highly satisfactory to note the very marked increase in the value of the mineral production of 1912 over that of all preceding years; the figures exceed those for 1911 by over a million and a quarter sterling, corresponding to a rise of nearly 17 per cent. Figures for individual minerals are almost equally satisfactory. There have been increases in the value of the outturn of most of the principal products such as coal, petroleum, manganese. salt, mica, wolfram, iron-ore and monazite, while in the case of only two minerals, lead and jadeite, has there been a considerable decrease in the output of any of the important products; in the case of jadeite the falling off was due to a reduced demand consequent on recent political disturbances in China.

Mineral concessions granted.

The number of licenses and leases granted during the year amounted to 622 as against 775 in 1911. More than half of these were prospecting licenses taken out in Burma. 113 prospecting licenses and 34 mining leases were granted in the Central Provinces.

II.—MINERALS OF GROUP I.

Chromite.	Graphite.	Magnesite.	Petroleum.	Saltpetre.
Coal.	Iron-ore.	Manganese-ore.	Ruby, Sapphire and Spinel.	Tin-ore.
Diamonds.	Jadeite.	Mica.		Tungsten-ore.
Gold.	Lead-ore.	Monazite.	Salt.	

Chromite.

The output of chromite during the year under review was about 24 per cent. below that of the previous year. The whole output which amounted to only 2,890 tons, with a value of £3,849, came from Baluchistan. The industry still remains a small one and continues to be largely dependent on the fluctuations of the market.

Coal.

The most important rise in the total value of the minerals produced during the year 1912 is due to coal, which accounts for considerably more than half the total increase, namely, the sum of £807,749, corresponding to an increase of 32·2 per cent. over the value of the outturn of the previous year. At the same time there was a considerable rise in pit's mouth value, from Rs. 2-11-4 to Rs. 3-6-0 per ton. Consequently the increase in the output was not so great as might be supposed from the rise in value. The total amount produced, however, amounted to nearly 14,750,000 tons, or nearly 16 per cent. more than was produced in the previous year, and nearly 2,000,000 tons more than was produced during the famous boom of 1908 when the output was over 12,750,000 tons, and the pit's mouth value rose to Rs. 3-15-0. With the exception of those of Baluchistan and Bengal most of the fields show a slight rise in pit's mouth value. In Baluchistan, however, the value fell from Rs. 10-11-1 in the previous year to Rs. 9-0-7 in 1912, whereas in the Jherria field the pit's mouth value rose to Rs. 2-14-1 and in the Raniganj field to Rs. 3-10-0.

TABLE 2.—*Average price (per ton) of Coal extracted from the Mines in each province during the year 1912.*

Province.	Average price per ton.
	Rs. A. P.
Assam	4 12 4
Baluchistan	9 0 7
Bengal	3 11 3
Bihar and Orissa	2 15 8
Central India	3 3 5
Central Provinces	4 1 8
Nizam's Territory	6 0 0
North-West Frontier Province	5 0 0
Punjab	5 3 2
Rajputana (Bikaner)	3 6 2

As usual the Gondwana fields produced nearly the whole of the output for the year.

TABLE 3.—*Origin of Indian Coal raised during 1911 and 1912.*

—	Average of last five years.	1911.	1912.
	Tons.	Tons.	Tons.
Gondwana Coalfields	11,704,312	12,329,458	14,298,083
Tertiary Coalfields	405,685	386,076	408,256
Total	..	12,715,534	14,706,339

There was a slight increase in the amount of coal exported during the year under review, the total quantity being 897,194 tons as against 860,788 tons in 1911. It is clear, therefore, that the increased amount produced in 1912 over that of 1911, amounting, as it does, to nearly 2,000,000 tons, must have been absorbed by the country. Of this increased consumption, the Indian railways are responsible for rather more than one-fifth, the total quantity of coal burned by them during the year being 4,590,618 tons as against 4,223,020 tons in 1911. There consequently remains a balance of increase of over 1½ million tons, most of which must have been employed in other industries. This is an indication of remarkably rapid industrial expansion.

TABLE 4.—*Exports of Indian Coal.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Aden	11,667	6,382	12,577	8,385
Ceylon	493,511	274,119	578,412	385,082
Straits Settlements . . .	224,794	124,846	148,391	101,799
Sumatra	109,319	64,687	119,427	80,027
Other countries	21,497	12,950	38,387	24,949
	860,788	*482,984*	897,194	*600,242*
Coke .	1,389	1,286	1,545	1,576
Total of Coal and Coke .	862,177	*484,270*	898,739	*601,818*

While the increase in the exports of coal was small the rise in imports was very considerable, namely, from 340,106 tons, including coke and patent fuel, in 1911, to 611,732 tons, or nearly double the amount, in the year under review. This is no doubt attributable to the increased use by steamships of coal other than Indian. There are marked increases in the amount of Natal and Japanese coal imported, a considerable increase, amounting to more than 100 per cent. in the imports of Australian coal, and a decrease in the imports of coal from the United Kingdom.

TABLE 5.—*Imports of Coal, Coke and Patent Fuel during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
From Australia (including New Zealand).	35,703	37,824	92,087	96,835
" Japan	6,795	6,975	97,288	102,570
" Natal	15,086	13,516	96,076	105,864
" United Kingdom . .	232,865	267,214	136,791	175,603
" Other countries . .	15,561	14,800	130,007	155,116
Total .	**306,010**	*340,329*	**552,249**	*635,988*
Coke	7,661	14,405	3,142	7,365
Patent Fuel	4,998	8,262	5,400	11,966
Government Stores . .	21,437	35,016	50 941	81,533
Total .	**340,106**	*398,012*	**611,732**	*736,842*

With the exception of Hyderabad (Singareni) and the North-West Frontier Province, the production of which latter is negligible, there was an increase in the outturn of every province. This increase was of course greatest in Bengal, Bihar and Orissa, that is to say, in the Raniganj and Jherria fields. Of the former the output increased from 4,311,956 tons to 4,944,268 tons and of the latter from 6,373,728 to 7,653,452 tons. Of the other Gondwana fields the output of Bellarpur in the Central Provinces decreased by about 10,000 tons and that of Singareni by over 20,000 tons. All the other fields show increases, the outturn of the new Hingir field in Sambalpur having risen from 5,669 tons to 21,314 tons.

TABLE 6.—*Provincial production of Coal during the years 1911 and 1912.*

Province.	1911.	1912.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Assam	294,893	297,160	2,267	..
Baluchistan	45,707	54,386	8,679	..
Bengal	11,468,904	4,306,129	1,963,610	
Bihar and Orissa	..	9,126,385		..
Central India	143,558	149,921	6,363	..
Central Provinces	211,616	233,996	22,380	..
Hyderabad	505,380	481,652	..	23,728
North-West Frontier Province	140	50	..	90
Punjab	30,575	38,409	7,834	..
Rajputana (Bikaner)	14,761	18,251	3,490	..
Total	**12,715,534**	**14,706,339**	*2,014,623*	*23,818*

TABLE 7.—*Output of Gondwana Coalfields for the years 1911 and 1912.*

Coalfields	1911.		1912.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Bengal, Bihar and Orissa—				
Daltonganj	70,662	·55	71,917	0·49
Giridih	704,443	5·54	730,530	4·97
Jherria	6,373,728	50·13	7,653,452	52·04
Rajmahal	1,978	·02	2,775	0·07
Ramgarh-Bokaro	468		8,258	
Raniganj	4,311,956	33·95	4,914,268	33·76
Sambalpur (Hingir-Rampur).	5,669		21,314	
Central India—				
Umaria	143,558	1·13	149,921	1·02
Central Provinces—				
Bellarpur	96,603	·76	86,417	0·59
Pench Valley	63,030	·50	90,722	0·62
Mohpani	51,983	·41	56,857	0·39
Hyderabad—				
Singareni	505,380	3·97	481,652	3·28
Total	**12,329,458**	**96·96**	**14,298,083**	**97·23**

Similarly all Tertiary fields show a steady rise in their outturn.

TABLE 8.—*Output of Tertiary Coalfields for the years 1911 and 1912.*

Coalfields.	1911.		1912.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent of Indian Total.
Assam—				
Makum . . .	294,893	2·32	296,615	2·02
Khasi and Jaintia Hills .			545	
Baluchistan—				
Khost	42,410	·33	45,477	0·31
Sor Range, Mach, etc. .	3,297	·03	8,909	0·06
North-West Frontier Province—				
Hazara	140		50	
Punjab (Salt Range)—				
Jhelum District . .	26,982	·24	33,192	0·26
Mianwali . . .	2,522		1,600	
Shahpur . . .	1,071		3,617	
Rajputana—				
Bikaner . . .	14,761	·12	18,251	0·12
Total .	**386,076**	**3·04**	**408,256**	**2·77**

There was a considerable rise in the total amount of labour employed in the coalfields during the year. The average number of persons employed daily was 132,567 as against 116,155 in 1911. There was also a slight increase in efficiency; the output per person employed rising from 109·47 tons in 1911 to 110·93 tons in the year under review. The number of deaths by accidents in the mines was 174 or one less than the number for the previous year, while the death rate per 1,000 persons employed fell from 1·5 to 1·3.

TABLE 9.—*Average number of persons employed daily in the Indian Coalfields during 1911 and 1912.*

Province.	Number of persons employed daily.		Output per person employed.	Number of deaths by accidents.	Death rate per 1,000 persons employed.
	1911.	1912.	1912.	1912.	1912.
Assam . . .	1,965	2,143	138·66	9	4·19
Baluchistan . .	932	1,161	46·84	10	8·61
Bengal . . .	99,983	36,828	116·92	39	1·05
Bihar and Orissa .	..	77,924	117·12	98	1·25
Central India . .	1,430	2,511	59·70	2	·79
Central Provinces .	2,292	2,530	92·48	1	·39
Hyderabad . .	7,800	8,315	57·92	15	1·80
North-West Frontier Province.	5	2	25	..	..
Punjab . . .	1,505	981	39·15	..	..
Rajputana (Bikaner) .	183	172	106·11	..	..
Total .	**116,155**	**132,567**	..	**174**	..
Average . . .	..	..	*110·93*	..	*1·3*

Diamonds.

There was again a decline in the output of diamonds, marked by a considerable fall in Central India and a slight rise in Madras. The industry is an insignificant one but a certain amount of attention has recently been paid to the possibility of exploitation of new areas in Central India and its effect will be probably shown in the figures for the outturn of the current year.

TABLE 10.—*Quantity and value of Diamonds produced in India during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Carats.	£	Carats.	£
Central India . .	44.21	475	8.57	400
Madras	8.75	3	19.17	11
Total .	**52·96**	*478*	**27·74**	*411*

Gold.

There was a slight rise, amounting to nearly 1½ per cent. in the outturn of gold during the year under review. Work has ceased in Dharwar but the reduction on this account was more than compensated for by the increased outturn in Mysore and Hyderabad and on the Anantapur field in Madras.

TABLE 11.—*Quantity and value of gold produced in India during 1911 and 1912.*

—	1911.		1912.		Labour.
	Quantity.	Value.	Quantity.	Value.	
	Oz.	£	Oz.	£	
Bombay—					
Dharwar	2,993	10,449	..	..	..
Burma—					
Myitkyina	6,390·38	24,269	4,994·77	18,931	154
Katha and Pakokku	22·28	110	15·16	75	4
Upper Chindwin	..	..	58·22	331	50
Hyderabad	13,726·4	52,070	16,993	64,980	1,516
Mysore	555,011	2,129,873	561,065	2,158,362	26,203
Madras	5,284	20,835	7,269	28,499	1,756
Punjab	134·62	518	147·52	583	289
United Provinces	5·5	19	12·25	45	90
Total	**583,567·18**	*2,238,143*	**590,554·92**	*2,271,806*	**30,062**

Graphite.

I regret to have to record the extinction during the past year of the Indian graphite industry. The value of the output from the only mine worked to any serious extent, namely, that in Travancore, fell from over £20,000 in 1910 to £9,425 in 1911. Owing to the difficulties of working, the mine was shut down at the beginning of the year under review and there is consequently no outturn for graphite in India for the year.

Iron-ore.

Both in Orissa and in Singbhum there was a considerable increase in the amount of iron-ore produced; the rapid rise in value of the output from a little under £10,000 in the year 1910 to nearly £50,000 in the year under review furnishes evidence of the activity of the Tata and the Bengal Iron and Steel Companies.

TABLE 12.—*Quantity and value of Iron-ore produced in India during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bengal, Bihar and Orissa—				
Burdwan	5,456	780	9,882	1,350
Orissa	300,000	20,000	471,232	31,415
Singhbhum	36,276	7,162	83,425	10,055
Other Districts	610	237	608	207
Bombay	1	..	1	..
Burma	20,995	5,599	12,563	3,350
Central India	585	156	476	127
Central Provinces	1,944	470	1,768	461
Hyderabad	223	59	..	..
Rajputana	100	27	50	13
United Provinces	22	6	24	6
Total	**366,212**	*34,496*	**580,029**	*47,044*

Jadeite.

The value of jadeite exported during the year 1912 was only about one quarter of that of the same mineral exported during the previous year. On the other hand the figures for production show only 806 cwts. with a value of £1,620 as produced during the same year. Attention has been drawn in previous Reviews to similar discrepancies and the only figures that can be regarded as even approximately accurate are those for export. They have therefore been taken to represent the value of production. Probably these are too small, since it is difficult to prevent a certain amount of the stone from being removed through unauthorised channels. The heavy fall in value of the amount exported as against the figures for the year 1911 is due to the disturbed condition of China during the year and the consequent restriction in the amount of trade to that country which is the chief purchaser of Burmese jadeite.

Lead-ore.

There was a decrease of nearly 10,000 tons in the amount of lead-ore and slag produced in Burma during the year under review; this amounts to a decline of nearly 27·7 per cent. Owing, however, to the average price of lead during the year having been over £18 per ton, the decline in value, amounting to £28,920, represents a percentage of only a little under 16. A small quantity of lead-ore was produced in the Drug district of the Central Provinces and the Kurnool district of Madras, the total amount being 163 tons, having an estimated pit's mouth value of £69.

TABLE 13.—*Production of Silver-lead-ore in Burma during 1911 and 1912.*

—	1911.			1912.		
	Quantity.	Value.		Quantity.	Value.	
	Lead-ore and slag.	Lead-ore and lead.	Silver.	Lead-ore and slag.	Lead-ore and lead.	Silver.
	Tons.	£	£	Tons.	£	£
Toungoo	140	587	..	..	..	..
Northern Shan States.	(ore) 3,218	2,169	2,642	(ore) 2,950	1,846	2,184
	(slag) 31,954	179,102(*a*)	8,933(*b*)	(slag) 22,563	150,984(*c*)	9,645(*d*)
Southern Shan States.	49	131	..	63	170	..
Total .	**35,361**	*181,989*	*11,575*	**25,576**	*153,000*	*11,829*

(*a*) Value of 12,793 tons of lead extracted.
(*b*) Value of 80,145 oz. of silver extracted.
(*c*) Value of 8,228 tons of lead extracted.
(*d*) Value of 76,220 oz. of silver extracted.

Magnesite.

The industry in this mineral is only a small one, but there was a considerable increase in production during the year, from 3,490 tons in 1911 valued at £1,047 to 15,379 tons valued at £4,614.

Manganese-ore.

Last year I had to record a fall of 10 per cent. in quantity and 23½ per cent. in value in the production of manganese-ore over that of the previous year. In the year under review, however, this falling off was more than made good by a rise of over 36 per cent. in the value of the outturn. At the same time there was a slight fall in the amount produced. The rise in the value of the total output is therefore due to improved prices and not to increased outturn, although no doubt the effect of these improved prices will be to reduce the existing stocks at the mines and lead to an increased output during the present year. The average value of first grade ore was 11·1*d.* and of second grade ore 10·8*d.* as against 9·5*d.* and 9·3*d.* in 1911.

TABLE 14.—*Quantity and value of Manganese-ore produced in India during 1911 and 1912.*

— —	1911.		1912.	
	Quantity.	Value f. o. b. at Indian ports.	Quantity.	Value f. o. b. at Indian ports.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Gangpur . . .	25,152	25,257	27,173	37,476
Bombay—				
Panch Mahals . .	45,330	45,519	43,538	60,046
Central India—				
Jhabua	7,319	6,068	5,652	6,688
Central Provinces—				
Balaghat . .	144,642	147,053	135,435	199,202
Bhandara . . .	119,606	121,600	115,365	169,683
Chhindwara . . .	1,540	1,566	16,517	24,294
Nagpur . . .	179,263	182,500	147,225	216,544
Madras—				
Sandur	66,950	53,002	62,488	71,080
Vizagapatam . . .	58,915	46,641	54,758	62,287
Mysore	21,573	19,595	29,293	37,104
Total .	**670,290**	*648,801*	**637,444**	*884,404*

Mica.

The increase in the value of the production of mica recorded in the last Review was maintained during 1912, when the output rose from nearly 34,000 cwt. to over 43,000 cwt., and the value of the mica exported rose by over 50 per cent., from £188,642 in 1911 to £284,290 in 1912.

TABLE 15.—*Quantity and Value of Mica produced in India during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
Bihar and Orissa	..	..	29,653	57,767
Bengal	25,225	43,499	..	..
Madras	7,462	25,852	13,484	36,815
Mysore	18	58	47	158
Rajputana	1,191	1,143	650·5	2,546
Total	**33,896**	*70,552*	**43,834·5**	*97,286*

Monazite.

This mineral has now taken an important place in the list of minerals of economic value produced in India. At present it is being worked only in Travancore. The output which amounted during the year 1911 to 832 tons valued at £24,044 rose in the year under review to 1,135 tons valued at £41,419. The property is in the hands of the London Cosmopolitan Mining Co., and as the figures are obtained from that Company through official channels the mineral has now been removed from Group II and placed in Group I, which include minerals for which fairly trustworthy returns are available.

Petroleum.

The output of Indian petroleum still continues steadily to increase and during last year exceeded, by nearly sixteen million gallons, the highest output previously recorded, namely that for the year 1909. The amount won during 1912 was over 249,000,000 gallons valued at £975,278. The deeper sands which have recently been tapped at Yenangyaung have led to a considerable increase in the production of the field. In the year 1911, the output fell to about 166,500,000 gallons from nearly 175,000,000 gallons in the previous year. Now, however, it has risen again to nearly 180,000,000 gallons. There has also been an increase in the output of Singu and a large increase in that of the Minbu field, although the total outturn of the latter is still quite small, amounting only to a little under 4,000,000 gallons. There was again a small increase in the output of the Digboi field in Assam.

The amount of paraffin wax exported again showed a considerable rise, from 247,679 cwt. in the year 1911 to 260,244 cwt. in the year under review.

TABLE 16.—*Quantity and Value of Petroleum produced in India during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Gallons.	£	Gallons.	£
Burma—				
Akyab	19,630	327	15,626	300
Kyaukpyu	36,970	913	41,304	943
Magwe (Yenangyaung)	166,494,319	640,856	170,802,842	692,082
Myingyan (Singu)	50,564,765	210,777	56,645,200	234,682
Pakokku (Yenangyat)	4,476,074	17,103	4,880,422	18,551
Minbu	632,458	2,635	3,896,365	16,235
Thayetmyo	1,315	12	53,450	114
Assam—				
Digboi (Lakhimpur)	3,565,163	11,760	3,747,359	12,361
Punjab—				
Mianwali	1,400	15	950	10
Total	**225,792,094**	*884,398*	**249,083,518**	*975,278*

There was also a reduction in the amount of foreign kerosene imported during the year. This fell from over 75 million gallons to a little under sixty-two and a half million gallons in 1912,

TABLE 17.—*Imports of Kerosene oil during 1911 and 1912.*

—	1911.	1912
	Gallons.	Gallons.
Borneo	11,400,224	12,540,042
Roumania	..	2,693,800
Russia	6,518,968	7,535,184
Straits Settlements	679,307	3,285,841
Sumatra	1,009,070	612,474
United States of America	55,602,821	35,684,624
Other Countries	9,004	688
Total	75,219,394	62,352,653

Ruby, Sapphire, and Spinel.

There was a slight increase amounting to nearly 3 per cent. in the outturn of the Ruby Mines, which rose from 288,213 carats valued at £67,594 in 1911 to 323,245 carats valued at £69,547 in 1912. The average number of labourers employed daily in the industry was 1,707.

TABLE 18.—*Quantity and Value of Ruby, and Sapphire and Spinel produced in India during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Carats.	£	Carats.	£
Burma—				
Mogok	(Rubies) 222,968	65,062	(Rubies) 250,987	66,838
Do	(Sapphires) 17,269	1,880	(Sapphires.) 18,552	1,987
Do.	(Spinels.) 47,976	652	(Spinels.) 53,706	722
Total	288,213	67,594	323,245	69,547

Salt.

The output of salt during the year 1912 was a little under 1,500,000 tons valued at £509,824. This represents an increase of nearly 10 per cent. on the output of the previous year.

TABLE 19.—*Quantity and Value of Salt produced in India during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Aden	100,392	39,939	143,681	57,244
Bengal	28	9	24	5
Bombay and Sind	468,328	111,374	546,459	129,201
Burma	26,235	90,251	30,845	108,150
Gwalior State	37	99	Not reported	..
Madras	414,521	137,652	484,405	161,844
Northern India	316,341	89,911	249,188	53,380
Total	**1,325,882**	*469,235*	**1,454,602**	*509,824*

There was a general rise in the output of rock salt, the total amount produced being over 157,000 tons.

TABLE 20.—*Quantity and Value of Rock-Salt produced in India during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Salt Range	124,605	14,987	131,234	15,406
Kohat	17,585	1,914	22,582	2,241
Mandi State	3,996	4,759	3,378	4,023
Total	**146,186**	*21,660*	**157,194**	*21,670*

The amount of salt imported was almost the same as that imported during the preceding year, namely, 551,689 tons in 1912 as against 551,560 tons in 1911.

Saltpetre.

Table 21 shows the respective quantities of saltpetre produced in India during the years 1911 and 1912. From this it will be seen that the actual output in 1912 was almost the same as in the preceding year; there was, however, a slight fall in value.

TABLE 21.—*Production of Saltpetre in India during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
North-West Frontier Province	12	213	12	257
Punjab	2,845	51,589	3,149	59,061
United Provinces	5,616	91,658	5,610	78,052
Bihar	5,818	73,847	5,687	75,626
Central India	23	166	..	..
Rajputana	360	2,752	339	3,136
Bombay (Cutch)	5	43	·5	3
Total	**14,679**	*220,268*	**14,797·5**	*217,035*

Table 22 shows the quantity and destination of saltpetre exported during the year.

TABLE 22.—*Distribution of Saltpetre exported during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
China	85,602	70,979	88,781	75,194
France	2,095	1,715	515	446
United Kingdom	52,130	42,744	38,005	33,411
United States of America	72,542	55,381	42,878	34,046
Other Countries	84,648	59,990	85,943	61,903
Total	**297,017**	*230,809*	**256,122**	*205,600*

Tin-ore.

The rise noted last year in the production of tin in Burma has been well maintained, the output having risen from 1,764 cwt. of block tin and 1,946 cwt. of tin-ore to 4,014 cwt. and 3,493 cwt. respectively. The rise in value of the output amounts to a little over £26,000, or over 104 per cent. of the output of the previous year. Working has now been taken up seriously in the Tavoy district where 1,258 cwt. of block tin were produced during the year.

The imports of block tin in 1912 amounted to 31,254 cwt. as against 35,001 in the previous year.

TABLE 23.—*Production of Tin-ore and Tin for the years 1911 and 1912.*

—	1911.				1912.			
	BLOCK TIN.		TIN-ORE.		BLOCK TIN.		TIN-ORE.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£	Cwt.	£	Cwt.	£
Burma—								
Mergui . . .	1,764	15,543	1,141	6,101	2,756	28,224	2,261	9,781
Southern Shan States.	..	..	802 (*a*)	3,260	..	..	1,202 (*a*)	4,808 (*a*)
Tavoy . . .	..	..	..	..	1,258	7,966	30	165
Total .	**1,764**	*15,543*	**1,943**	*9,361*	**4,014**	*36,190*	**3,493**	*14,754*

(*a*) Includes figures for wolfram.

Tungsten-ore.

The output of wolfram in Burma again increased during the year 1912, and rose from 1,308 tons in the previous year to $1,671\frac{1}{2}$ tons in the year under review. As usual most of this came from Tavoy, but the output of Mergui was more than doubled, and rose to a little under 219 tons.

Although much of the wolfram output is derived from lode mining in Tavoy, not a single mining lease had been issued up to the end of the year 1912 either in that district or in Mergui. Nevertheless, as pointed out in last year's *Review*, extensive mining operations are being carried on merely under prospecting licenses. The output of the mines in the Southern Shan States rose from 40 tons to 60 tons.

TABLE 24.—*Production of Tungsten-ore during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Burma—				
Mergui	103	8,525	217·8	16,963
Southern Shan States	40	3,260	60·1	4,808
Tavoy	1,165	88,204	1,393·4	93,407
Central Provinces—				
Nagpur	..	..	·2	22
Total	**1,308**	*99,989*	**1,671·5**	*115,200*

III.—MINERALS OF GROUP II.

Alum. There was slight decrease in the production of alum, which fell from 6,479 cwt. in 1911 valued at £2,819 to 5,546 cwt. valued at £2,627 in the year under review. Practically the whole output came from the Mianwali district of the Punjab.

Amber. The output of amber increased by 13 cwt., the output for 1912 being 27 cwt. valued at £179 as against 14 cwt. in the previous year.

Bauxite. Nine-hundred-fifty tons of bauxite, valued at £516, were produced in the Central Provinces.

Building stones, etc. The returns under the head of Building Stones show a rise of 10 per cent. on the preceding year, the value being £270,980 as against £246,446. It has already been pointed out that the returns are incomplete, but even the figures available show that the item is an important one.

TABLE 25.—*Production of Building Materials and Road Metal in India during 1912.*

	NATURE OF MATERIALS.																	
—	GRANITE.		LATERITE.		LIME.		LIMESTONE AND KANKAR.		MARBLE.		SANDSTONE.		SLATE.		TRAP.		MISCELLANEOUS.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons	£
Assam . .	..	..	..	..	..	..	79,486	7,428	..	..	..	..	..	..	..	..	..	..
Baluchistan .	..	..	..	..	..	..	292	477	..	..	..	..	..	..	..	..	..	..
Bengal . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Bihar and Orissa.	9,374	2,044	15,186	1,898	..	..	87,469	12,715	..	..	30,527	7,532	2,000	2,460	25,750	854	195,449	10,375
Bombay .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Burma . .	343,008	32,230	178,098	29,269	..	..	223,857	12,740	..	..	120,582	7,163	..	..	..	..	174,411	18,353
Central India .	..	..	..	..	27,836	13,184	41,713	1,264	..	..	..	..	..	..	..	..	60	3
Central Provinces.	..	..	..	..	..	..	93,664	6,022	..	..	..	..	..	..	..	..	878	9
Hyderabad .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Not reported.	953
Madras . .	341,592	3,938	670,929	4,532	..	..	608,322	26,019	..	..	234,000	1,587	..	..	..	..	379,741	13,290
Punjab . .	..	..	..	..	..	..	10,096	56	..	..	35,747	2,519	7,991	7,786	..	..	228,724	7,401
Rajputana .	..	..	..	..	..	..	801	478	2,303	9,826	..	..	..	..	..	..	34,328	2,861
United Provinces.	..	..	..	..	43	40	65	10	..	..	..	..	114,940	554	..	..	197,599	23,112
* TOTAL .	693,974	38,212	864,213	35,699	27,879	13,224	1,145,765	67,207	2,303	9,826	420,856	18,801	124,931	10,800	25,750	854	1,211,190	76,357

The production of clay, chiefly for the manufacture of bricks and unglazed pottery, is returned as 1,009,240 tons valued at £66,187. The returns include no figures for the United Provinces or for Bihar and Orissa.

Clay.

The Cape Copper Company continued their energetic exploitation of the copper lodes of Singhbhum and produced during the year 8,984 tons of ore valued at £13,476. If this Company meets with the success that its enterprise deserves, copper will soon take its placea mong the more important mineral products of India. The total outturn during 1912 was 9,619 tons valued at £13,709 as against only 2,238 tons valued at £3,404 during 1911.

Copper.

There was a considerable rise in the output of corundum, from 3,676 cwt. in 1911 to 8,707 cwt. in 1912. The greater part of this came from Mysore and Madras, but 1,400 cwt. were produced in Assam. The total value of the production for the year was £1,295.

Corundum.

There was a slight decrease in the amount of garnet won during the year as against the production for 1911. The total production was 192 cwt., valued at £1,176. Practically the whole of this came from Kishengarh.

Garnet.

There was considerable activity in the production of gypsum during 1912, the output having risen to 21,033 tons from a total of 9,193 tons produced during the preceding year. 14,440 tons were derived from the well-known Jamsar deposit in Bikaner, 4,756 tons from Marwar and 1,837 tons from the Jhelum district.

Gypsum.

The output of ochre increased, but amounted only to 1,719 tons valued at £161. The chief sources of supply were Central India and the Drug district of the Central Provinces.

Ochre.

A slightly larger quantity of platinum was obtained during the operations of the Burma Gold Dredging Syndicate at Myitkyina in the course of the year 1912. The amount, however, was only 56·60 ozs. valued at £386 as against 37·73 ozs. valued at £244 in 1911.

Platinum.

A small quantity of samarskite was again won from the Nellore mica mines. The total amount was 29 cwt. valued at £81 as against 24 cwt. valued at £89, obtained during the preceding year.

Samarskite.

Steatite.

There was a considerable increase, chiefly due to Jubbulpore and Hamirpur, in the output of steatite during 1912. The total production is returned as 15,746 cwt. valued at £1,429.

TABLE 26.—*Quantity and Value of Steatite produced in India during 1911 and 1912.*

—	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
Burma—				
Minbu	..	..	260	107
Myitkyina.	..	..	82	62
Pakokku Hill Tracts . .	12·5	9	34	26
Central Provinces—				
Jubbulpore	8,816	588	11,200	560
Madras—				
Kurnool	3,320	221	..	..
Bellary	..	..	150	1
Nellore	126	340	800	24
United Provinces—				
Hamirpur	..	..	2,740	549
Jhansi	56	67	480	100
Total .	**12,330·5**	*1,225*	**15,746**	*1,429*

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 27.—*Statement of Mineral Concessions granted during 1912.*

ASSAM.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Khasi and Jaintia Hills.	(1) Mr. E. D. Coggan	Corundum	P. L.	3,344·64	1st April 1912	6 months and 10 days.
Do.	(2) Do.	Do.	P. L. (renewal).	9,363·2	11th October 1912.	1 year.
Do.	(3) Do.	Do.	P. L. (renewal).	3,344·64	Do.	Do.
Do.	(4) Messrs. Tata Sons & Co.	Mineral Oil	P. L.	7,040	31st October 1912.	Do.
Lakhimpur	(5) Babu Sewnarayan Beria.	Coal	M. L.	1,280	1st April 1910	20 years.
Do.	(6) Assam Railway and Trading Co. Ltd.	Coal, oil, slate, shale, iron and other metals, exclusive of gold, silver and precious stones.	P. L.	12,800	21st September 1912.	1 year.
Naga Hills	(7) Assam Company	Coal	M. L.	2,728·93	1st January 1912.	30 years.
Nowgong	(8) Mr. F. L. H. Koch	Do.	P. L.	12,800	12th November 1912.	1 year.

BALUCHISTAN.

Kalat	(9) Baluchistan Coal Co.	Coal	M. L.	80	1st July 1911	30 years.
Do.	(10) Sirdar Bahawal Khan Satikzai.	Do.	M. L.	80	Do.	Do.
Zhob	(11) Khan Bahadur B. D. Patel, C.I.E.	Chromite	M. L.	91	Do.	Do.

BENGAL.

Chittagong	(12) Burma Oil Co.	Mineral oil	P. L. (renewal).	3,671	15th April 1912.	1 year.

BIHAR AND ORISSA.

Hazaribagh	(13) Mr. G. B. Knowles	Mica	P. L.	320	16th January 1912.	1 year.

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BIHAR AND ORISSA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh	(14) Mr. C. A. Dickson .	Mica . .	P. L. .	40	15th December 1911.	1 year.
Do.	(15) Mr. W. Snell on behalf of Mr. A. Jardine.	Do. . .	P. L. .	160	7th February 1912.	Do.
Do. .	(16) Mr. A. Jardine .	Do. . .	P. L. .	33·15	4th May 1912	Do.
Do. .	(17) Do. .	Do. . .	P. L. .	80	20th April 1912.	Do.
Do. .	(18) Mr. W. H. Murray .	Do. . .	M. L. .	160	4th March 1912.	30 years.
Do. .	(19) Babu Baidya Nath Saha.	Do. . .	P. L. .	160	22nd March 1912.	1 year.
Do. .	(20) Mr. S. D. Philippe	Do. . .	M. L. .	8·83	10th April 1912.	30 years.
Do. .	(21) Babus Nagendra Nath Samanta and Satya Kinkar Sahana.	Do. . .	P. L. .	120	28th May 1912.	1 year.
Do. .	(22) Mr. E. Myers .	Do. . .	P. L. .	80	18th May 1912.	Do.
Do. .	(23) Babus Nagendra Nath Samanta and Satya Kinkar Sahana.	Do. . .	P. L. .	80	11th May 1912.	Do.
Do. .	(24) Babu Bagala Prasanna Mazumdar.	Do. . .	P. L. .	160	12th May 1912.	Do.
Do. .	(25) Mr. Charles A. Dickson.	Do. . .	P. L. .	80	6th April 1912	Do.
Do. .	(26) Babus Nagendra Nath Samanta and Satya Kinkar Sahana.	Do. . .	P. L .	40	18th March 1912.	Do.
Do. .	(27) Babu Santosh Kumar Mazumdar.	Do. . .	P. L. .	274	29th March 1912.	Do.
Do. .	(28) Mr. C. P. Andrews .	Do. . .	P. L. .	4·05	20th August 1912.	Do.
Do. .	(29) Babu Ananga Ranjan Chatterji.	Do. . .	P. L. .	100	9th August 1912.	Do.
Do. .	(30) Messrs. Tata Sons & Co.	Do. . .	P. L. .	120	20th July 1912.	6 months
Do. .	(31) Babu Shivji Walji	Do. . .	P. L. .	47·56	2nd September 1912.	1 year.
Do. .	(32) Babu Bijoy Chandra Bose.	Do. . .	M. L. .	1·67	15th May 1912.	30 years.
Do. .	(33) Babu Satyendra Pado Sarkar.	Do. . .	M. L. .	80	4th July 1912	Do.
Do. .	(34) Mr. Archibald A. C. Dickson.	Do. . .	M. L. .	80	24th January 1912.	Do.

E. L.—*Exploring License.* P. L.—*Prospecting License.* M. L.—*Mining Lease.*

BIHAR AND ORISSA—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Iazaribagh .	(35) Babu Baidya Nath Saha.	Mica . .	M. L. .	146·5	5th June 1912	30 years.
Do. .	(36) Mr. Archibald A. C. Dickson.	Do. . .	P. L. .	360	30th January 1912.	1 year.
Do. .	(37) Babu Shivji Walji .	Do. . .	P. L. .	200	6th November 1912.	Do.
Do. .	(38) Mr. A. Jardine .	Do. . .	P. L. .	114·48	9th December 1912.	Do.
ambalpur .	(39) The Hingir Rampur Coal Co. Ltd., Bombay.	Coal. . .	P. L. (renewal for one year).	1,123·52	25th May 1911.	Do.
Do	(40) Do. . . .	Do. . .	P. L. (renewal).	1,123·52	25th May 1912.	Do.
Do. .	(41) Mr. Thomas Pressick Yeoman of Kotabaga, Jharsuguda, Bengal-Nagpur Railway.	Do. . .	P. L. .	1,300	27th November 1912.	Do.
inghbhum .	(42) Messrs. Schröder, Smidt & Co., Calcutta.	Manganese . .	P. L. .	1,472	15th January 1912.	Do.
Do. .	(43) Bengal Iron and Steel Co., Ltd., Kulti.	Iron-ore . .	P. L. .	1,088	10th May 1912.	Do.
Do. .	(44) Do. . . .	Do. . .	P. L. .	281·6	Do.	Do.
Do. .	(45) Mr. T. H. Bennertz	Galena and its associates.	P. L. .	About 3,200	5th July 1912.	Do.
Do. .	(46) Bengal Iron and Steel Co., Ltd., Kulti.	Iron-ore . .	M. L. .	About 3,840	10th July 1912.	2 years.
Do. .	(47) Roy Srinath Pal Bahadur.	Manganese . .	P. L. .	About 1,920	9th August 1912.	1 year.
Do .	(48) Bengal Iron and Steel Co., Ltd., Kulti.	Iron-ore . .	M. L. .	281·6	28th August 1912.	30 years.
Do. .	(49) Babu Krishna Chandra Dey, Calcutta.	Manganese . .	P. L. .	249·6	18th July 1912.	1 year.

BOMBAY.

anara .	(50) The Nagpur Manganese Mining Syndicate.	Manganese . .	E. L. .	1,510	27th February 1912.	1 year.
Do. .	(51) Do. . . .	Do. . .	E. L. .			

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BOMBAY—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kanara .	(52) The Nagpur Manganese Mining Syndicate.	Manganese . .	E. L. .	801	11th May 1912.	1 year.
Do. .	(53) Khimji, Cooverji of Bombay.	Do. . .	E. L. .	1,885	4th June 1912.	Do.
Do. .	(54) Messrs. Byramji Pestonji & Co., Nagpur.	Do. . .	E. L. .	1,020	6th June 1912.	Do.
Panch Mahals	(55) Mr. Karimbhai Shamsuddin of Godhra.	Do. . .	P. L. .	156	15th June 1912.	Do.
Do. .	(56) Do. . . .	Do. . .	E. L. .	816	21st August 1912.	Do.
Ratnagiri .	(57) Messrs. Schröder Smidt & Co., Bombay.	All Minerals .	E. L. .	4,871	13th November 1912.	Do.

BURMA.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Amherst .	(58) Maung Pe . .	Wolfram . .	P. L. .	2,240	17th June 1912.	1 year.
Do. .	(59) Maung Thein Zan .	All minerals (except mineral oil).	P. L. .	640	9th August 1912.	Do.
Do. .	(60) Ma Saw Nyun .	Do. . .	P. L. .	1,280	22nd August 1912.	Do.
Do. .	(61) T. D'Castro & Son .	Do. . .	P. L. .	1,280	4th October 1912.	Do.
Do. .	(62) Maung Kyan .	Wolfram, gold, silver and copper.	P. L.	2,080	4th November 1912.	Do.
Do. .	(63) Do. . . .	Tin, wolfram, gold silver and copper.	P. L. .	2,080	Do.	Do.
Do. .	(64) Maung Kin . .	All minerals (except mineral oil).	E. L. .	Kawkareik Township (except Forest reserves.)	7th November 1912.	Do.
Do. .	(65) Maung Thein Zan .	Do. . .	P. L. .	2,880	28th November 1912.	Do.
Do. .	(66) T. D'Castro & Son .	All minerals .	E. L. .	Whole of the Amherst District except forest reserves.	Do.	Do.
Bhamo . .	(67) Laban Yeik and four others.	Gold . .	E. L. .	6,400	27th June 1912.	Do.
Katha . .	(68) Moolla Dawood .	Gold, silver, lead, copper and mica.	P. L. .	640	11th June 1912.	7 months
Do. . .	(69) Maung Tun Mau .	Gold, silver, copper, tin and lead.	P. L. .	751·36	7th May 1912	7 months and 24 days.

E. L.—*Exploring License.* P. L.—*Prospecting License.* M. L.—*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Katha . .	(70) Mr. S. G. Calogreedy	Silver and lead .	P. L. .	2,560	11th June 1912	7 months.
Do. . .	(71) Mr. R. H. Pocklington.	Copper, gold, silver, lead, tin, iron, coal, asbestos and zinc.	P. L. . (renewal).	220	29th May 1912	7 months and 3 days.
Do. . .	(72) C. Soon Thin .	Lead . . .	P. L. . (renewal).	2,464	11th June 1912.	7 months.
Do. . .	(73) Maung Nyo . .	Lead and silver .	P. L. . (renewal).	960	13th July 1912.	6 months (up to 31st December 1912).
Magwe . .	(74) Maung Tun Aung Gyaw.	Petroleum . .	P. L. .	1,280	23rd October 1911.	1 year.
Do. . .	(75) The Moolla Oil Co., Ltd.	Do. . .	P. L. . (renewal).	960	29th September 1911.	Do.
Do. .	(76) Messrs. Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. . (renewal).	1,280	9th April 1912	Do.
Do. . .	(77) Abu Bucker . .	Mineral oil . .	P. L. .	2,880	8th November 1912.	Do.
Do. . .	(78) Ma Kin le . .	Do. . .	P. L. .	383	7th November 1912.	Do.
Do. . .	(79) Messrs. Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	640	12th November 1912.	Do.
Do. . .	(80) Messrs. Rangoon Oil Co., Ltd.	Do. . .	P. L. . (renewal).	2,240	19th February 1912.	From 15th February 1911 to 30th October 1911.
Mandalay .	(81) Mr. R. N. Iyer .	Lead and silver .	P. L. .	2,560	7th April 1911	1 year.
Do.	(82) Moolla Moosaji .	All minerals (except oil).	E. L. .	Whole district excluding reserved forests.	4th March 1912	Do.
Do. .	(83) Messrs. The Burma Mines, Ltd.	Iron-ore . .	M. L. .	66·56	7th January 1910.	10 years.
Meiktila .	(84) W. Noor . .	All minerals (except mineral oil).	E. L. .	12·80	20th July 1912.	1 year.
Mergui . .	(85) Maung Saw Maung	All minerals (except oil).	P. L. .	1,625·60	30th March 1912.	Do.
Do. .	(86) Maung Pe Gyi .	Do. .	P. L. .	2,124·80	18th January 1912.	Do.
Do. .	(87) Mahomed . .	Do. .	P. L. .	2,780·16	Do. .	Do.
Do. .	(88) Mr. H. A. Foy .	Do. .	P. L. .	1,495·04	6th February 1912.	Do.
Do .	(89) Maung Shwe Thi .	Do. .	P. L. .	1,710·08	28th February 1912.	Do.
Do. .	(90) Maung Shwe Yeik .	Do. .	P. L. .	3,200	Do.	Do.

E. L.=Exploring License. P. L.=Prospecting License. M. L.=Mining Lease.

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term
Mergui . .	(91) Ung Kyi Hoe .	All minerals (except oil).	P. L. .	3,200	18th January 1912.	1 year.
Do. . .	(92) Maung Mya . .	Wolfram, gold, tin and allied metals.	P. L. .	1,800·92	16th February 1912.	Do.
Do. . .	(93) W. La Gale . .	All minerals (except oil).	P. L. .	280·08	18th January 1912.	Do.
Do. . .	(94) Mahomed Haniff .	Do. .	P. L. .	2,688·16	6th March 1912	Do.
Do. . .	(95) Do. .	Do. .	P. L. .	3,192·32	Do. .	Do.
Do. . .	(96) Do. .	Do. .	P. L. .	3,148·80	18th January 1912.	Do.
Do. . .	(97) A. Jalil . .	Do. .	P. L. .	2,867·20	8th January 1912.	Do.
Do. . .	(98) U. Ne Gyi . .	Do. .	P. L. .	3,200	2nd January 1912.	Do.
Do. . .	(99) Do. . .	Do. .	P. L. .	3,200	20th March 1912.	Do.
Do. . .	(100) Do. . .	Do. .	P. L. .	3,200	1st February 1912.	Do.
Do. . .	(101) Mr. C. Kitchin .	Tin . . .	P. L. (renewal).	640	21st January 1912.	Do.
Do. . .	(102) U. Shwe L . .	All minerals (except oil).	P. L. .	3,200	8th January 1912.	Do.
Do. . .	(103) Maung Kya Sin .	Do. .	P. L. .	1,966·08	9th March 1912	Do.
Do. . .	(104) U. Bwa . .	Do. .	P. L. .	1,433·10	1st February 1912.	Do.
Do. . .	(105) U. Ne Gyi .	Do. .	P. L. .	2,703·36	23rd January 1912.	Do.
Do. . .	(106) Ong Pe Kin .	Do. .	P. L.	540·16	19th January 1912.	Do.
Do. . .	(107) Messrs. Moolla Dawood Sons & Co.	Do. .	P. L. .	2,211·84	28th February 1912.	Do.
Do. . .	(108) U. Shwe Ni . .	Do. .	P. L.	2,088·96	31st January 1912.	Do.
Do. . .	(109) Maung Kin . .	Do.	P. L. .	465·92	28th February 1912.	Do.
Do. . .	(110) Messrs. Moolla Dawood Sons & Co.	Do. .	P. L. .	3,200	Do. .	Do.
Do. . .	(111) Do. .	Do . .	P. L. .	3,123·20	Do. .	Do.
Do. . .	(112) Do. .	Wolfram . .	P. L. .	3,056·64	Do. .	Do.
Do. . .	(113) Do. .	All minerals (except oil).	P. L. .	3,200	Do. .	Do.
Do. . .	(114) C. Soo Don . .	Do. .	P. L. .	2,088·30	12th March 1912.	Do.

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(115) Maung Kyin Ton and one other.	All minerals (except oil).	P. L. .	998·40	21st March 1912.	1 year.
Do. . .	(116) Messrs. Bume and Reif.	Do. .	P. L. .	2,862·08	29th January 1912.	Do.
Do. . .	(117) Do. .	Do. .	P. L. .	49·007	Do. .	Do.
Do. . .	(118) U. Shwe I . .	Do. .	P. L. .	1,845·76	2nd February 1912.	Do.
Do. . .	(119) Messrs. Bume and Reif.	Do. .	P. L. .	517·84	29th January 1912.	Do.
Do. . .	(120) Do. .	Do. .	P. L. .	435·20	Do. .	Do.
Do. . .	(121) Khaw Moh Oo .	Do. .	P. L. .	1,228·80	12th March 1912.	Do.
Do. . .	(122) Mr. M. E. Bhymiah	Do. . .	P. L. .	3,200	29th March 1912.	Do.
Do. . .	(123) Maung Po Thaik .	Do. .	P. L. .	1,766·40	21st March 1912.	Do.
Do. .	(124) Messrs. Moolla Dawood Sons & Co.	Do. .	P. L. .	3,200	29th February 1912.	Do.
Do. . .	(125) Do. .	Do. .	P. L .	2,554·88	Do.	Do.
Do. . .	(126) U. Shwe I. . .	Do. .	P. L. .	3,200	10th April 1912.	Do.
Do. . .	(127) U. La Gale . .	Do. .	P. L. .	2,730·36	15th May 1912	Do.
Do. . .	(128) Maung Thein Pe .	Do. .	P. L. .	199·68	31st May 1912	Do.
Do. . .	(129) Maung E. Gyi .	Do. .	P. L. .	2,560	21st June 1912.	Do.
Do. . .	(130) Maung Ko Yin Gyi	Do. .	P. L. .	5,170·84	7th June 1912	Do.
Do. . .	(131) Messrs. Moolla Dawood Sons & Co.	Do. .	P. L. .	3,200	2nd April 1912.	Do.
Do. . .	(132) M. E. Bhymiah .	Do. .	P. L .	3,200	12th April 1912.	Do.
Do. . .	(133) Maung Kya Sin .	Do. .	P. L. .	3,200	7th June 1912	Do.
Do. . .	(134) Messrs. Moolla Dawood Sons & Co.	Do. .	P. L. .	3,200	27th May 1912	Do.
Do. . .	(135) Maung Shwe I. .	Do. .	P. L. .	3,200	28th May 1912	Do.
Do. . .	(136) A. Jalil .	Do. .	P. L. .	3,200	Do. .	Do.
Do. . .	(137) Maung Shwe I. .	Do. .	P. L. .	3,200	7th June 1912	Do.
Do. . .	(138) Do. .	Do. .	P. L. .	3,200	Do. .	Do.
Do. . .	(139) Messrs. Moolla Dawood Sons & Co.	Wolfram . .	P. L. .	3,200	5th June 1912	Do.
Do. . .	(140) Maung Kyaw E. .	All minerals (except oil).	P. L. .	3,180·8	14th May 1912	Do.
Do. . .	(141) S. Adamjee . .	Do. .	P. L. .	2,880	21st June 1912	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui . .	(142) U. Shwe I. . .	All minerals (except oil).	P. L. .	3,200	1st June 1912	1 year.
Do. . .	(143) C. Soo Don . .	Wolfram, gold, tin and allied minerals.	P. L. .	381·44	5th September 1912.	Do.
Do. . .	(144) Messrs. S. R. Balldon and H. A. Pearson.	All minerals (except mineral oil).	E. L. .	3,200	12th August 1912.	Do.
Do. . .	(145) Lim Aw Kyi .	Do. .	P. L. .	163·84	25th July 1912	Do.
Do. . .	(146) Do. .	Do. .	P. L. .	1,392·64	18th September 1912.	Do.
Do. . .	(147) Maung Shwe Kyi .	Do. .	P. L. .	2,662·40	Do. .	Do.
Do. . .	(148) Maung Kin . .	Do. .	P. L. .	1,019·60	27th September 1912.	Do.
Do. . .	(149) Lim Aw Kyi .	Do. .	P. L. .	43·52	19th September 1912.	Do.
Do. . .	(150) G. Shwe Yin .	Do. .	E. L. .	Area not specified.	27th September 1912.	Do.
Do. . .	(151) E. Ahmed . .	Do. .	P. L. . (renewal)	2,898·56	28th July 1912	Do.
Do. . .	(152) Chia Boon Teat .	Do. .	E. L. . (renewal).	Area not specified.	13th July 1912	Do.
Do. . .	(153) Hadji Ismail .	Do. .	P. L. .	2,509	13th November 1912.	Do.
Do. . .	(154) Maung Shwe Yaik	Do. .	P. L. .	3,199·92	12th December 1912.	Do.
Do. . .	(155) Abdul Raman .	Do. .	E. L. .	Whole district.	15th November 1912.	Do.
Do. . .	(156) Sit Shu . .	Do. .	P. L. . (renewal).	3,200	26th November 1912.	Do.
Do. . .	(157) E. Ahmed . .	Do. .	P. L. . (renewal).	2,316·80	31st October 1912.	Do.
Do. . .	(158) Maung Shwe Yaik	Do. .	P. L. . (renewal).	2,406·20	1st November 1912.	Do.
Do. . .	(159) Maung Ne Gyi .	Do. .	P. L. . (renewal).	3,176·36	6th December 1912.	Do.
Minbu . .	(160) Maung Aung Ba .	Petroleum . .	P. L. .	5,120	17th August 1911.	Do.
Do. . .	(161) The British Borneo and Burma Petroleum Syndicate.	Do. .	P. L. .	358·4	26th October 1911.	Do.
Do. . .	(162) Mr. H. Fenton .	Do. .	P. L. .	1,280	29th February 1912.	Do.
Do. . .	(163) Maung Tun Aung Gyaw.	Do. .	P. L. .	1,290·54	Do. .	Do.
Do. . .	(164) Mr. F. C. Macdonald	Do. .	P. L. .	1,280	Do. .	Do.

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Minbu . .	(165) Maung Taik Gyi and one.	Petroleum . .	P. L. .	320	29th February 1912.	1 year.
Do. . .	(166) Maung Ne Dun .	Do. .	P. L. .	320	Do. .	Do.
Do. . .	(167) Annamalay Chetty	Do. .	P. L. .	2,560	3rd November 1911.	Do.
Do. . .	(168) Abu Bucker .	Do. .	P. L. .	320	4th April 1912	Do.
Do. . .	(169) Maung Kyi Tha and Maung Tun Wa.	Do. .	P. L. .	1,440	4th July 1912	Do.
Do. . .	(170) Maung Po Kin	Do. .	P. L. .	6,880	5th July 1912	Do.
Do. . .	(171) Ebrahim Kaka .	Do. .	P. L. .	2,880	13th August 1912.	Do.
Do. . .	(172) Dada Somar .	Do. .	P. L. .	256	20th September 1912.	Do.
Do. . .	(173) Maung Taik Gyi .	Mineral oil . .	P. L. .	201	7th November 1912.	Do.
Do. . .	(174) Mr. H. P. Cameron	Do. .	P. L. .	493	23rd October 1912.	Do.
Do. . .	(175) Manset Co. . .	Do. .	P. L. .	522·24	14th November 1912.	Do.
Do. . .	(176) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. .	440·32	27th November 1912.	Do.
Do. . .	(177) The Irrawaddy Petroleum Oil Syndicate, Ltd.	Do. . .	P. L. .	640	17th June 1912	Do.
Do. . .	(178) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. .	174	20th November 1912.	Do.
Do. . .	(179) Mr. H. P. Cameron	Do. . .	P. L. .	2,560	4th November 1912.	Do.
Do. . .	(180) Messrs. The British Burma Petroleum Co., Ltd.	Do . .	P. L. .	640	7th December 1912.	Do.
Do. . .	(181) Maung Yin Gyi .	Do. . .	P. L. .	1,452	28th October 1912.	Do.
Do. . .	(182) Sahib Ally . .	Do. . .	P. L.	1,280	18th October 1912.	Do.
Do. . .	(183) M. E. Bhymiah & Co.	Do. . .	P. L. .	1,280	13th November 1912.	Do.
Do. . .	(184) Ebrahim Kaka .	Do. . .	P. L. .	1,280	3rd October 1912.	Do.
Do. . .	(185) Thaha . .	Do. . .	P. L. .	492	13th November 1912.	Do.
Do. . .	(186) Abu Bucker .	Do. . .	P. L. .	261·47	23rd October 1912.	Do.
Do. . .	(187) Do. .	Do. . .	P. L. .	1,280	Do. .	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Minbu . .	(188) Amarshi Gopal .	Mineral oil . .	P. L. .	160	28th September 1912.	1 year.
Do. . .	(189) Ahmed Abdul Karim.	Do. . .	P. L. .	960	18th October 1912.	Do.
Do. . .	(190) Maung Shwe Hlaing.	Do. . .	P. L. .	307·5	23rd October 1912.	Do.
Do. . .	(191) Messrs. The United Company.	Do. . .	P. L. .	2,329·60	27th November 1912.	Do.
Do. . .	(192) Messrs. The Moolla Oil Co., Ltd.	Do. . .	P. L. (renewal).	2,240	1st March 1912	From 15th February 1911 to 30th October 1911.
Do. .	(193) Do. .	Do. . .	P. L. (renewal).	2,529	5th April 1912	1 year.
Do. . .	(194) Maung Ne Dun .	Do. .	P. L. (renewal).	5,440	4th July 1912	Do.
Myingyan .	(195) Maung Maung Pe	Petroleum . .	P. L. (renewal).	Block 50 N. 640	29th August 1911.	Do.
Do. .	(196) The Rangoon Oil Co., Ltd.	Do. . .	P. L. (renewal).	Block 54 N. 640	15th February 1911.	Do.
Do. .	(197) Messrs. Nath Singh Oil Co., Ltd.	Do. . .	P. L. (renewal).	640	14th November 1911.	Do.
Do. .	(198) Maung Aung Ba .	Do. . .	P. L. (renewal).	903·68	12th October 1911.	Do.
Do. .	(199) Messrs. The Nath Singh Oil Co.	Do. . .	P. L. (renewal)	2,560	10th October 1911.	Do.
Do. .	(200) Messrs. Shwe Oh Bros. & Co.	Do. . .	P. L. .	800	3rd January 1912.	Do.
Do. .	(201) Do.	Do. . .	P. L. .	800	3rd July 1912	Do.
Do. .	(202) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	425·60	10th July 1912	Do.
Do. .	(203) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. .	640	11th July 1912	Do.
Do. .	(204) Maung Oh and Maung Charley.	Mineral oil . .	M. L. .	1,920	11th May 1912	30 years.
Do .	(205) Mulla Ebrahim, Fatima Bibi and Rasul Bibi.	Do. . .	P. L. .	1,920	9th November 1912.	1 year.
Do. .	(206) Mr. A. H. Tucker .	Do. . .	P. L. .	Block 57 N. .	17th November 1912.	Do.
Do. .	(207) Maung Po Kin .	Wolfram, Jasper and precious stones.	P. L. .	2,560	1st December 1912.	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres	Date of commencement.	Term.
Myingyan .	(208) Messrs. The Burma Oil Co., Ltd.	Mineral oil . .	P. L. .	1,320	28th January 1912.	1 year.
Do. .	(209) Maung Po Kin .	Do. . .	P. L. . (renewal).	483·35	23rd June 1912	Do.
Do. .	(210) Messrs. Rangoon Oil Co., Ltd.	Do. . .	P. L. . (renewal).	640	15th February 1911.	From 15th February 1911 to 30th October 1911.
Do. .	(211) Mr. A. H. Tucker .	Do. . .	P. L. . (renewal).	1,280	23rd March 1912.	1 year.
Myitkyina. .	(212) Mr. A. R. Oberlander.	Copper, silver and iron.	P. L. . (renewal).	640	31st October 1911.	Do.
Do. .	(213) Mr. B. A. Baldwin	Platinum . .	P. L. .	3,360	3rd September 1912.	Do.
Do. .	(214) Do. .	Do. . .	P. L. .	4,800	10th December 1912.	Do.
Do. .	(215) Do. .	Gold, platinum and minerals of the platinum group.	P. L. .	7,680	Do. .	Do.
Northern Shan States.	(216) W. R. Hillier .	Lead and allied metals.	P. L. . (renewal).	960	26th February 1911.	Do.
Do. .	(217) Mr. J. Shepherd .	Coal . . .	P. L. .	3,200	19th June 1912	Do.
Do. .	(218) Mr. W. R. Hillier .	Galena and allied minerals.	P. L. .	960	7th August 1912.	Do.
Do. .	(219) Hkun Hsang Awn	Lead, silver and allied minerals.	P. L. .	640	24th December 1912.	Do.
Do. .	(220) Messrs. The Burma Mines, Ltd.	Silver, lead, iron and copper.	P. L. . (rrnewal).	3,200	18th December 1912.	Do
Pakokku .	(221) Mr. S. S. Agabob .	Petroleum . .	P. L. .	1,920	3rd February 1912.	Do.
Do. .	(222) Maung Maung .	Do. . .	P. L. .	1,361·92	25th January 1912.	Do.
Do. .	(223) Mr. M. Goolam Hussein Surty.	Do. . .	P. L. .	2,560	6th March 1912	Do.
Do. .	(224) The Rangoon Oil Co., Ltd.	Do. . .	P. L. . (renewal).	Block No. 124 (Yenangyat).	26th April 1912	Do.
Do. .	(225) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	744·96	8th March 1912	Do.
Do. .	(226) Mr. C. E. Brown .	Do. . .	P. L. .	2,560	16th April 1912	Do.
Do. .	(227) Maung Tha Ya and Maung Po Kan.	Mineral oil . .	P. L. .	99·84	12th October 1912.	Do.
Do. .	(228) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	1,440	17th October 1912.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

P 2

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Pakokku .	(229) Mr. R. P. Wilcox on behalf of W. Mansfield.	Mineral oil . .	P. L. (2nd renewal).	1,280	5th October 1912.	1 year.
Do .	(230) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	351·65	25th July 1912	Do.
Do. .	(231) Messrs. The Moolla Oil Co., Ltd.	Do. . .	P. L. (renewal).	3,520	4th March 1912	From 15th February 1911 to 30th October 1911.
Pegu . .	(232) Mr. W. R. Fox .	Gold and tin .	P. L. (renewal).	5,670·40	29th June 1912	1 year.
Prome . .	(233) Messrs. The Burma Oil Co., Ltd.	Petroleum . .	P. L. (renewal).	3,200	31st May 1912	Do.
Do. . .	(234) Mr. A. H. Tucker .	Mineral oil . .	P. L. .	8,960	2nd October 1912.	Do.
Do. . .	(235) Maung Thu Daw of Yenangyaung.	Do. . .	P. L. (renewal).	2·10	19th July 1912	Do.
Ruby Mines .	(236) Maung Taung Laung.	All minerals (except oil).	E. L. .	86·42	1st February 1912.	Do.
Do. .	(237) Mawlabi Golam Murtaza.	Precious stones .	E. L. .	40	2nd April 1912	Do.
Sagaing .	(238) C. Soon Thin .	Petroleum . .	P. L. .	3,190	17th February 1912.	Do.
Do. .	(239) J. M. Seik Kyat .	Copper-ore . .	P. L.	9,561·6	14th June 1912	Do.
Salween .	(240) Mr. N. Samwell .	Gold . . .	P. L.	3,200	16th October 1912.	Do.
Do. .	(241) Maung Pan Aung .	Precious stones and other minerals (excluding mineral oil).	E. L. .	640	Do. .	Do.
Shwebo .	(242) Messrs. The Indo-Burma Petroleum Co., Ltd.	Petroleum . .	P. L. (renewal).	5,120	19th September 1912.	Do.
Do. . .	(243) Do. .	Do. . .	P. L. (renewal).	1,280	25th September 1912.	Do.
Southern Shan States.	(244) Mr. J. Dumoulin .	Gold and Silver .	P. L. .	160	20th March 1912.	Do.
Do. .	(245) Lt.-Col. G. Rippon	Tungsten, tin, copper and associated minerals.	P. L. .	2,560	4th January 1912.	Do.
Do. .	(246) Messrs. Moolla Dawood Sons & Co.	Gold, silver, copper and lead.	P. L.	640	7th February 1912.	Do.
Do. .	(247) Mr. J. Dumoulin.	Gold and associated minerals.	P. L. .	1,547	5th June 1912	Do.
Do. .	(248) Mr. D. E. Smith	Coal . . .	P. L. (renewal).	3,200	8th June 1912	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Southern Shan States.	(249) Mr. N. Samwell .	Gold, copper, tin and allied minerals.	P. L. (renewal) .	3,200	26th June 1912.	1 year.
Do. .	(250) Mr. R. H. Ady .	All minerals (except mineral oil).	P. L. (renewal) .	2,560	26th April 1912.	Do.
Do. .	(251) Maung Yaing .	Silver and lead .	P. L. (renewal) .	400	20th July 1912.	Do
Do. .	(252) Maung Kya Ywet	Lead and silver .	M. L. .	$2\frac{1}{10}$	1st September 1912.	5 years.
Do. .	(253) Mr. J. C. Cross .	Copper and other minerals (except mineral oil).	P. L. .	3,200	14th November 1912.	1 year.
Do. .	(254) Tan Po Yin on behalf of the Hon'ble Mr. Lim Chin Tsong.	All minerals (except mineral oil).	P. L. (renewal).	2,120	27th October 1912.	Do.
Do. .	(255) Mr. W. R. Hillier .	Antimony, lead, silver and tin.	P. L. (renewal).	960	23rd October 1912.	Do.
Tavoy . .	(256) Mr. T. Fowle .	All minerals (except oil).	P. L. .	5,027·84	10th February 1912.	Do.
Do. . .	(257) The Tenasserim Concessions, Ltd.	Do. .	P. L. .	1,011·2	3rd January 1912.	Do.
Do. . .	(258) Tan Po Chong .	Do. .	P. L. .	3,200	Do.	Do.
Do. .	(259) The Tenasserim Concessions, Ltd.	Do. .	P. L. .	1,920	Do. .	Do.
Do. . .	(260) Messrs. Shwe Oh Bros. & Co.	Do. .	P. L. .	2,560	25th November 1911.	Do.
Do. . .	(261) Maung Pet . .	Do. .	P. L. .	458·24	2nd February 1912.	Do.
Do. . .	(262) Swan Huat & Co. .	Do. .	P. L. .	440	7th February 1912.	Do.
Do. . .	(263) Ma Tha . .	Do. .	P. L. .	1,062·40	9th February 1912.	Do.
Do. . .	(264) Messrs. Mower & Co.	Do. .	P. L. .	1,344·56	3rd January 1912.	Do.
Do. . .	(265) Ong Hoe Kyin .	Do. .	P. L. .	386·20	8th February 1912.	Do.
Do. . .	(266) The Tenasserim Concessions, Ltd.	Do. .	P. L. .	1,110	20th March 1912.	Do.
Do. . .	(267) Ma Sein Daing .	Do. .	P. L. .	446·88	2nd February 1912.	Do.
Do. . .	(268) Maung E Cho .	Do. .	P. L. .	2,668	Do.	Do.
Do. . .	(269) Khoo Shwe Gun .	Do. .	P. L. .	1,946·72	9th January 1912.	Do.
Do. . .	(270) Tan Po Chong .	Do. .	P. L. .	1,756·16	2nd February 1912.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(271) E. Ahmed . .	All minerals (except oil).	P. L. .	838·65	8th February 1912.	1 year.
Do. . .	(272) Khoo Sin Haing .	Do. .	P. L. .	709·60	6th February 1912.	Do.
Do. .	(273) Maung Lu Pe .	Do. .	P. L. .	2,622·08	Do. .	Do.
Do. .	(274) Tan Byaw Seng .	Do. .	P. L. .	293·44	20th February 1912.	Do.
Do. . .	(275) M. H. Merican .	Do. .	P. L. .	882	3rd January 1912.	Do.
Do. . .	(276) Tan Byaw Seng .	Do. .	P. L. .	1,080·80	24th January 1912.	Do.
Do. . .	(277) Tan Chong Yeau .	Do. .	P. L. .	587·72	15th February 1912.	Do.
Do. . .	(278) Messrs. Ba Thaung Bros. & Co.	Do. .	P. L. .	587·72	16th February 1912.	Do.
Do. . .	(279) Mr. S. Crawshaw .	Do. .	P. L. .	1,270	3rd January 1912.	Do.
Do. . .	(280) The Tenasserim Concessions, Ltd.	Do. .	P. L. .	2,000	8th March 1912.	Do.
Do. . .	(281) Qua Cheng Tock .	Do. .	P. L. .	3,200	3rd January 1912.	Do.
Do. . .	(282) Qua Cheng Guan .	Do. .	P. L. .	3,200	Do. .	Do.
Do. . .	(283) Mr. J. R. Booth .	Do. .	P. L. .	3,109·40	23rd March 1912.	Do.
Do. . .	(284) Maung Tun Mya .	Do. .	P. L. .	708·80	2nd February 1912.	Do.
Do. . .	(285) Maung Po Thwin .	Do. .	P. L. .	708·80	Do. .	Do.
Do. . .	(286) Tan Po Chong .	Do. .	P. L. .	825	Do. .	Do.
Do. . .	(287) Lim Shain .	Do. .	P. L. .	1,227·52	6th February 1912.	Do.
Do. . .	(288) Mr. A. S. Jamal .	Do. .	P. L. .	2,530	15th February 1912.	Do
Do. . .	(289) Mrs. L. Penna .	Do. .	P. L. .	3,152·36	8th January 1912.	Do
Do. . .	(290) Messrs. Moolla Dawood Sons & Co.	Do. .	P. L. .	1,079·68	25th January 1912.	Do.
Do. . .	(291) Mr. E. Ahmed .	Do. .	P. L. .	2,444·80	23rd March 1912.	Do.
Do. . .	(292) Mr. J. R. Booth .	Do. .	P. L. (renewal).	3,200	20th July 1911.	6 months.
Do. . .	(293) The Tavoy Concessions, Ltd.	Do. .	P. L. (renewal).	2,112	10th September 1911.	1 year.
Do. . .	(294) Messrs. Moolla Dawood Sons & Co.	Do. .	P. L. .	113·60	7th February 1912.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(295) The Rangoon Mining Co.	All minerals (except oil)	P. L. . (renewal).	3,200	25th September 1911.	1 year.
Do. .	(296) C. Soo Don . .	Do. .	P. L. . (renewal).	2,080	1st November 1911.	Do.
Do. . .	(297) Messrs. Moolla Dawood Sons & Co.	Do. .	P. L. .	1,107·02	20th February 1912.	Do.
Do. . .	(298) Do. .	Do. .	P. L. .	1,920	Do.	Do.
Do. . .	(299) Messrs. The Hitakaree & Co.	Do. .	P. L. . (renewal).	2,880·30	3rd December 1911.	Do.
Do. . .	(300) Ahyu Shouk .	Do. .	P. L. .	789·76	10th February 1911.	Do.
Do. . .	(301) The Tenasserim Concessions, Ltd.	Do. .	P. L. .	2,560	20th March 1912.	Do.
Do. . .	(302) Khoo Jin Taik .	Do. .	P. L. . (renewal).	3,200	7th January 1912.	Do.
Do. . .	(303) Khoo Kim Cheng .	Do. .	P. L. . (renewal).	3,200	6th January 1912.	Do.
Do. . .	(304) The Tenasserim Concessions, Ltd.	Do. .	P. L. . (renewal).	1,280	9th December 1911.	Do.
Do. . .	(305) Qua Cheng Guan .	Do. .	P. L. . (renewal).	1,477	23rd December 1911.	Do.
Do. . .	(306) The Tavoy Exploration Syndicate.	Tin, wolfram and allied minerals.	P. L. .	1,600	20th March 1912.	Do.
Do. . .	(307) Do. .	Do. .	P. L. .	722	Do.	Do.
Do. . .	(308) Mr. P. P. Murphy .	Do. .	P. L. . (renewal).	667	1st February 1912.	Do.
Do. . .	(309) The Hermingyi Mining Co., Ltd.	All minerals (except oil).	P. L. . (renewal).	3,200	24th December 1911.	Do.
Do. . .	(310) The Tavoy Exploration Syndicate.	Wolfram . .	P. L. .	1,216	20th February 1912.	Do.
Do. . .	(311) The Hindu Choung Tin Dredging and Mining Co.	All minerals (except oil).	P. L. . (renewal).	3,200	20th January 1912.	6 months.
Do . .	(312) Maung Hpaw .	Do. .	P. L. . (renewal).	460	25th January 1912.	1 year
Do. . .	(313) Ma Mo Thu . .	Do. .	P. L. . (renewal).	3,200	7th December 1911.	Do.
Do. . .	(314) Mr. B. C. Simeons	Do. .	P. L. . (renewal).	656	19th January 1912.	Do.
Do. . .	(315) The Heinze Bay Tin Dredging and Mining Co.	Do. .	P. L. .	3,200	28th March 1912.	Do.
Do. .	(316) The Tenasserim Concessions, Ltd.	Do. .	P. L. .	1,146·88	12th April 1912.	Do

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(317) Yeo Eng Byan .	All minerals (except oil).	P. L.	3,186	27th May 1911.	1 year.
Do. . .	(318) Tan Shwe Cho .	Do. .	P. L. .	3,148·8	16th May 1912.	Do.
Do. . .	(319) Do. .	Do. .	P. L. .	3,187·2	Do. .	Do.
Do. . .	(320) Messrs. Marshall Cotterell & Co., Ltd.	Do. .	P. L. .	3,115·50	1st May 1912	Do
Do. . .	(321) Messrs. Mower Cotterell & Co.	Do. .	P. L. .	3,200	Do. .	Do.
Do. . .	(322) Swee Seng & Co. .	Do. .	P. L. .	1,951	2nd April 1912.	Do.
Do. . .	(323) Messrs. Mower & Co.	Do. .	P. L. .	3,200	1st May 1912	Do.
Do. . .	(324) The Tenasserim Concessions, Ltd.	Do. .	P. L. .	3,002	Do. .	Do.
Do. . .	(325) Messrs. A. C. Martin and C. H. dePaulsen.	Do. .	P. L. .	3,200	20th April 1912.	Do.
Do. . .	(326) Messrs. Min Gyaw Bros. & Co.	Do. .	P. L. .	3,195	25th April 1912.	Do
Do. . .	(327) M. Lubbai Saib .	Do. .	P. L. .	3,088·38	18th April 1912.	Do.
Do. . .	(328) S. Adamjee . .	Do. .	P. L. .	1,050	17th May 1912	Do.
Do. .	(329) M. Lubbai Saib .	Do. .	P. L. .	1,280	10th April 1912.	Do.
Do. . .	(330) Mrs. L. Penna .	Do. .	P. L. .	2,060·50	17th April 1912.	Do.
Do. . .	(331) Maung Tun Mya .	Do. .	P. L. .	2,999·60	10th April 1912.	Do.
Do. . .	(332) Yeo Eng Byan .	Do. .	P. L. . (renewal).	550	31st May 1912	Do.
Do. . .	(333) Do. .	Do. .	P. L. . (renewal).	2,536	2nd December 1911.	Do.
Do. . .	(334) Maung Po Thein .	Do. .	P. L. . (renewal).	2,090·88	11th November 1911.	Do.
Do. . .	(335) Messrs. Radcliff & Co.	Do. .	P. L. . (renewal).	4,320	12th April 1912.	Do.
Do. . .	(336) Messrs. The Hitakaree & Co., Ltd.	Do. .	P. L. . (renewal).	2,918·34	3rd December 1911.	Do.
Do. . .	(337) Leong Shwe Sin .	Do. .	P. L. . (renewal).	2,712	9th December 1911.	Do.
Do. . .	(338) Maung E. Cho .	Do. .	P. L. .	741·40	12th April 1912.	Do.
Do. .	(339) Burma Malaya Mines, Ltd.	Do. .	P. L. . (renewal).	2,854·4	1st November 1911.	Do.

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BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(340) Lim Kya Yan .	All minerals (except oil).	P. L. . (renewal).	3,195	26th January 1912.	1 year.
Do. . .	(341) Burma Malaya Mines, Ltd.	Do. . .	P. L. (renewal).	3,200	1st January 1912.	Do.
Do. . .	(342) Burma Malaya Mines, Ltd.	Do. . .	P. L. . (renewal).	1,920	30th December 1911.	Do.
Do. .	(343) Khoo Tun Byan .	Do. . .	P. L. . (renewal).	2,772·22	25th January 1912.	Do.
Do. . .	(344) Messrs. Radcliff & Co.	Do. . .	P. L. . (renewal).	6,240	30th December 1911.	Do.
Do. .	(345) Messrs. Shwe Oh Brothers & Co.	Do. . .	P. L. .	3,200	18th September 1912.	Do.
Do. .	(346) Messrs. Radcliff & Co.	Do. . .	P. L. .	16,000	3rd November 1911.	Do.
Do. .	(347) Khoo Tun Byan & Co.	Do. . .	P. L. .	2,256	9th April 1912	Do.
Do. .	(348) Mr. T. J. Mackay .	Do. . .	P. L. . (renewal).	2,409·23	23rd May 1912	Do.
Do. .	(349) Messrs. Radcliff & Co.	Do. .	P. L. . (renewal).	2,722	24th March 1912.	Do.
Do. .	(350) The Tenasserim Concessions, Ltd.	Do. . .	P. L. .	2,907·8	17th October 1912.	Do.
Do. .	(351) Mr. W. S. Wood .	Do. .	P. L. .	138·65	4th October 1912.	Do.
Do. .	(352) Ahyu Shoak. .	Do. . .	P. L. .	1,689·60	9th October 1912.	Do.
Do. .	(353) Mr. E. M. Nana .	Do. . .	P. L. .	1,273	18th October 1912.	Do.
Do. .	(354) Kyong Nga . .	Do. . .	P. L. . (renewal).	2,581·12	28th May 1912	From 15-2-1911 to 30-10-1911.
Thaton .	(355) Maung Sein Swe .	Do. . .	P. L. .	6,681·6	9th January 1911.	1 year.
Do. . .	(356) Mr. C. E. Law .	Do. . .	P. L. .	5,888	2nd February 1912.	Do.
Do. . .	(357) Ma Chein . .	Do. . .	P. L. .	4,697·6	4th January 1912.	Do.
Do. . .	(358) Maung Shan Byn .	Do. . .	P. L. .	998·4	5th January 1912.	Do.
Do. . .	(359) Ma Chein . .	Do. . .	P. L. .	3,180·8	4th January 1912.	Do.
Do. . .	(360) Moti Rahman .	Do. . .	P. L. .	2,892·8	5th January 1912.	Do.
Do .	(361) Sein Nga . .	Do. . .	P. L. .	1,696	12th January 1912.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thaton . .	(362) The Hon'ble Mr. Lim Chin Tsong.	All minerals (except oil).	P. L. .	736	9th January 1912.	1 year.
Do. .	(363) Maung Pan E. .	Do. . .	P. L. .	2,176	18th March 1912.	Do.
Do. .	(364) Mr. S. Solomon . .	Do. . .	P. L. .	5,760	3rd April 1912	Do
Do. .	(365) Moti Rahman .	Do. . .	P. L. .	2,931·2	19th April 1912.	Do.
Do. .	(366) Maung Ba Leik .	Do. . .	P. L. .	3,878·4	24th April 1912.	Do.
Do. .	(367) Mr. H. Watson .	Do. . .	P. L. .	396·8	30th July 1912.	Do.
Do. .	(368) S. Lefevre . .	Do. . .	P. L. .	716·8	20th August 1912.	Do.
Do. .	(369) Shwe Oh Bros. & Co.	Do. . .	P. L. .	4,012·8	6th October 1912.	Do.
Do. .	(370) Su Kyu Lye . .	Do. . .	P. L. .	8,652·8	19th November 1912.	Do.
Do. .	(371) U Shan Byu . .	Do. . .	P. L. .	8,960	27th November 1912.	Do.
Thayetmyo .	(372) Maung Tun . .	Petroleum . .	P. L. .	222·80	13th December 1911.	Do.
Do. .	(373) Maung Tha Daw .	Do. . .	P. L. .	3,002·80	13th December 1911.	Do.
Do. .	(374) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. .	94·72	22nd May 1912.	Do.
Do. .	(375) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	5,760	6th January 1912.	Do.
Do. .	(376) Maung Tun Aung Gyaw.	Mineral oil . .	P. L. .	4,000	4th October 1912.	Do.
Do. .	(377) Do. . .	Gold . .	P. L. .	1,920	4th October 1912.	Do.
Do.	(378) Abu Bucker .	Mineral oil . .	P. L. .	3,968	12th October 1912.	Do.
Do. .	(379) Mr. J. A. Murray .	Do. . .	P. L. .	3,840	28th November 1912.	Do.
Do.	(380) Messrs The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	4,480	30th May 1912.	Do.
Do.	(381) Do. . .	Do. . .	P. L. (renewal).	2,840	18th July 1912	Do.
Do.	(382) Do. .	Do. .	P. L. (renewal).	5,200	23rd October 1912.	Do.
Do.	(383) Do. . .	Do. . .	P. L. (renewal).	640	29th August 1912.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thayetmyo .	(384) Messrs. The Burma Oil Co., Ltd.	Mineral oil . .	P. L. . (renewal).	1,400	29th August 1912.	1 year.
Do. .	(385) Do. . .	Do.	P. L. . (renewal).	640	23rd October 1912.	Do.
Toungoo .	(386) Maung Po Tha .	Gold, silver, tin, iron and wolfram.	P. L. .	1,600	10th January 1912.	Do.
Do. .	(387) Do. . .	Do. . .	P. L. .	1,600	13th May 1912.	Do.
Upper Chindwin.	(388) Mr. W. Cooper	Petroleum . .	P. L. .	40,960	30th April 1912.	Do.
Do. .	(389) Do. . .	Coal and other minerals (except oil).	P. L. .	40,960	30th April 1912.	Do.
Do. .	(390) Messrs. The Indo-Burma Petroleum Co., Limited.	Petroleum . .	P. L. .	11,520	12th September 1912.	Do.
Do. .	(391) Do. . .	Do. . .	P. L. .	12,800	12th September 1912.	Do.
Do. .	(392) Gowri Shankar Mythye.	Coal . .	E. L. .	10,400	28th September 1912.	Do.

CENTRAL PROVINCES.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(393) Mr. Byramji Pestonji.	Manganese . .	M. L. .	328	4th January 1912.	30 years.
Do. .	(394) Messrs. Lalbihari and Ramcharan.	Mica . .	M. L. .	171	25th March 1912.	5 years.
Do. .	(395) Central India Mining Company.	Manganese . .	M. L. .	272	25th January 1912.	30 years.
Do. .	(39) Mr. C. Vela Ayah .	Do. . .	M. L. .	45	18th January 1912.	Do.
Do. .	(397) Messrs. Schröder Smidt & Co.	Do. . .	P. L. .	212	25th March 1912.	1 year.
Do. .	(398) Do. . .	Do. . .	E. L. .	30	Do. .	Do.
Do. .	(399) Mr. Byramji Pestonji.	Do. . .	M. L. .	22	4th January 1912.	30 years.
Do. .	(400) Do. . .	Do. . .	M. L. .	20	Do. .	Do.
Do. .	(401) Do. . .	Do. . .	M. L. .	81	29th March 1912.	Do.
Do. .	(402) Messrs. Rattanchand Kesrichand Chullancy & Sons.	Do. . .	P. L. .	69	17th January 1912.	1 year.
Do. .	(403) Indian Mineral Mining Syndicate.	Do. . .	E. L. .	19	25th March 1912.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(404) Messrs. Schröder Smidt & Co.	Manganese . .	P. L. . (renewal).	100	19th December 1911.	3 months.
Do. .	(405) Mr. Byramji Pestonji	Do. . .	P. L. . (renewal).	332	7th January 1912.	1 year.
Do. .	(406) Babu Kripa Shankar.	Do. . .	E. L. .	768	25th March 1912.	Do.
Do. .	(407) Mr. C. Velu Ayah .	Do. . .	P. L. .	6	30th May 1912	Do.
Do. .	(408) Messrs. L. R. Ramchandra & Co.	Do. . .	P. L. .	8	24th June 1912.	Do.
Do. .	(409) Nagpur Manganese Mining Syndicate.	Do. .	P. L. . (renewal).	20	2nd April 1911.	2 years.
Do. .	(410) Indian Mineral Mining Syndicate.	Do. . .	P. L. .	119	24th June 1912.	1 year.
Do. .	(411) Do. . .	Do. . .	E. L. .	10,452	12th June 1912.	Do.
Do. .	(412) Central India Mining Co.	Do. .	E. L. .	1,814	24th June 1912.	Do.
Do. .	(413) Do. . .	Do. .	E. L. .	671	Do. .	Do.
Do. .	(414) Indian Mineral Mining Syndicate.	Do. . .	E. L. .	3,605	12th June 1912.	Do.
Do. .	(415) Do. . .	Do. . .	E. L. .	2,214	6th June 1912	Do.
Do. .	(416) Do. . .	Do. .	E. L. .	724	Do. .	Do.
Do. .	(417) Mr. Byramji Pestonji.	Do. . .	P. L. . (renewal).	96	9th April 1912	Do.
Do. .	(418) Lala Ganesh Prasad and Bros.	Do. . .	P. L. . (renewal).	188	10th February 1912.	6 months.
Do. .	(419) Mr. Byramji Pestonji.	Do. . .	P. L. . (renewal).	136	2nd May 1912	Do.
Do. .	(420) Lala Ganesh Prasad and Bros.	Do. . .	P. L. . (renewal).	338	6th June 1912	Do.
Do. .	(421) Tata Iron and Steel Co., Ltd.	Do. .	M. L. .	600	24th September 1912.	5 years.
Do. .	(422) Netra Manganese Co., Ltd.	Do. . .	M. L. .	56	12th September 1912.	30 years.
Do. .	(423) Sir Kasturchand Daga, K.C.I.E.	Do. . .	P. L. .	130	22nd August 1912.	1 year.
Do. .	(424) Do. . .	Do. . .	E. L. .	72	Do. .	Do.
Do. .	(425) Mr. Kripa Shankar	Do. . .	M. L. .	145	9th September 1912.	30 years.
Do. .	(426) Mr. Byramji Pestonji.	Do. . .	P. L. .	115	20th August 1912.	1 year.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(427) Mr. Kripa Shankar	Manganese . .	M. L. .	66	9th September 1912.	30 years.
Do. .	(428) Seth Dhowakalmal Ganpatlal.	Do. . .	P. L. .	134	20th August 1912.	1 year.
Do. .	(429) Do. . .	Do. . .	E. L. .	211	Do. .	Do.
Do. .	(430) Mr. Madhulal Dugar.	Do. . .	P. L. .	18	7th August 1912.	Do.
Do. .	(431) Do. . .	Do. . .	E. L. .	18	Do. .	Do.
Do. .	(432) Messrs. Bahmansha Fouzdar Bros.	Do. . .	P. L. .	221	18th July 1912	Do.
Do. .	(433) Mr. Kripa Shankar	Do. . .	P. L. .	87	11th September 1912.	Do.
Do. .	(434) Netra Manganese Co., Ltd.	Do. . .	M. L. .	16	10th July 1912.	Will expire with the original lease, dated 18-8-08 to which it is supplementary.
Do. .	(435) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do.	E. L. .	111	18th July 1912.	1 year.
Do. .	(436) Do. do. .	Do. . .	P. L. .	84	22nd August 1912.	Do.
Do. .	(437) Do. do. .	Do. . .	E. L. .	19	Do. .	Do.
Do. .	(438) Indian Mineral Mining Syndicate.	Do. . .	P. L. .	101	20th August 1912.	Do.
Do. .	(439) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. .	34	22nd August 1912.	Do.
Do. .	(440) Mr. Kripa Shankar	Do. . .	P. L. .	621	23rd September 1912.	Do.
Do. .	(441) Rai Sahib Hira Lal Sukul.	Do. . .	M. L. .	83	3rd October 1912.	30 years.
Do. .	(442) India Mineral Mining Syndicate.	Do. . .	E. L. .	920	23rd September 1912.	1 year.
Do. .	(443) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. .	13	22nd August 1912.	Do.
Do. .	(444) Do. do. .	Do. . .	E. L. .	38	Do. .	Do.
Do. .	(445) Mr. Byramji Pestonji.	Do. . .	M. L. .	52	12th October 1912.	30 years.
Do. .	(446) Sir Kasturchand Daga, K.C.I.E.	Do. . .	M. L. .	11	21st November 1912.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(447) Messrs. Lalbehari Naraindas and Ramcharan Shankerlal.	Manganese . .	P. L. .	28	2nd November 1912.	1 year.
Do. .	(448) Seth Mahamandram Sheonarain.	Do. . .	P. L. (renewal).	59	27th July 1912.	6 months.
Betul .	(449) Khan Bahadur M. M. Mulna.	Coal . . .	M. L. .	1,032	11th January 1912.	30 years.
Do. . .	(450) Mr. Muhammad Bakar Khan.	Bauxite . .	P. L. .	96	15th June 1912.	1 year.
Do. . .	(451) Muhammad Bakar Khan.	Mica . . .	E. L. .	100	24th September 1912.	Do.
Do. . .	(452) Messrs. Nazar Ali and Muhammad Husain.	Manganese . .	P. L. .	124	24th November 1912.	Do.
Do. .	(453) Do. do. .	Mica . . .	E. L. .	180	24th October 1912.	Do.
Do. . .	(454) Do. do. .	Manganese . .	E. L. .	124	Do. .	Do.
Do. . .	(455) Mr. Muhammad Bakar Khan.	Mica . .	E. L. .	151	9th October 1912.	Do.
Bhandara .	(456) Mr. Shamji Madhoji.	Manganese . .	M. L. .	25	17th February 1912.	30 years.
Do. .	(457) Mr. E. C. Dungore	Do. . .	M. L.	42	4th January 1912.	Do.
Do. .	(458) Seth Gowardhan Das.	Do. .	E. L. .	274	31st January 1912.	1 year.
Do. .	(459) Indian Mineral Mining Syndicate.	Do. . .	P. L. .	124	19th March 1912.	Do.
Do. .	(460) Mr. Byramji Pestonji.	Do. . .	P. L. (renewal).	9	9th February 1912.	3 months.
Do. .	(461) Seth Gowardhan Das.	Do. . .	P. L. .	172	29th May 1912.	1 year.
Do. .	(462) Messrs. Schröder Smidt and Company.	Do. . .	P. L. (renewal).	295	5th May 1912	3 months.
Do. .	(463) Mr. Lakshman Damodhar Lele.	Do. . .	P. L. (renewal).	83	22nd April 1912.	Do.
Do. .	(464) Messrs. Brahmadatta and Baijnath.	Do. . .	P. L. (renewal).	198	22nd April 1912.	Do.
Do. .	(465) Do. do. .	Do. . .	P. L. (renewal).	106	26th May 1912.	6 months.
Do. .	(466) Mr. Byramji Pestonji.	Do. . .	P. L. (renewal).	91	26th July 1912.	Do.
Do. .	(467) Messrs. Schröder Smidt and Company.	Do. . .	P. L. (renewal).	295	5th August 1912.	1 month and 27 days.
Do.	(468) The Indian Manganese Company, Ltd.	Do. . .	P. L. .	45	24th November 1912.	1 year.

E. L. = Exploring License. P. L. = Prospecting License. M. L. = Mining Lease.

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara .	(469) Mr. Byramji Pestonji	Manganese . .	P. L. . (renewal).	125	7th November 1912.	6 months.
Bilaspur .	(470) Mr. W. J. Considine.	Coal and iron ore	P. L. .	11,623	28th March 1912.	1 year.
Do. .	(471) Do. do. .	Coal . . .	E. L. .	13,301	19th June 1912.	Do.
Do. .	(472) Do. do. .	Do. . .	E. L. .	19,532	19th June 1912.	Do.
Do. .	(473) Mr. P. C. Dutt .	Do. . . .	E. L. .	33,408	2nd September 1912.	Do.
Do. .	(474) Diwan Bahadur Ballabhdass and Mr. P. C. Dutt.	Do. . . .	E. L. .	34,726	Do. .	Do.
Chanda .	(475) Messrs. M. Kanhayalal and Verma.	Do. . . .	E. L. .	10,895	22nd June 1912.	Do.
Chhindwara .	(476) The Hon'ble Mr. M.B. Dadabhoy, C.I.E.	Manganese . .	P. L. .	220	8th January 1912.	Do.
Do. .	(477) Mr. John Brown .	Coal . . .	M. L. .	270	21st March 1912.	30 years.
Do. .	(478) Messrs. H. Verma and Kanhayalal.	Manganese . .	P. L. .	381	19th January 1912.	1 year.
Do. .	(479) Mr. Byramji Pestonji.	Do. . .	P. L. . (renewal).	172	6th January 1912.	Do.
Do. .	(480) Messrs. Macbeth Brothers & Co.	Coal . . .	M. L. .	6,400	25th April 1912.	30 years.
Do. .	(481) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Manganese . .	P. L. . .	106	1st April 1912	1 year.
Do. .	(482) Messrs. H. Verma and Kanhayalal.	Do. . .	P. L. .	463	10th May 1912.	Do.
Do. .	(483) Do. do. .	Do. . .	P. L. .	430	1st May 1912	Do.
Do .	(484) Messrs. Shaw, Wallace and Company.	Coal . . .	P. L. . . (renewal).	5,460	23rd March 1912.	Do.
Do. .	(485) Messrs. H. Verma and Kanhayalal.	Manganese . .	P. L. .	313	4th May 1912	Do.
Do. .	(486) Do. do. .	Do. . .	P. L. .	93	10th June 1912.	Do.
Do. .	(487) Messrs. Shaw, Wallace & Co. (Pench Valley Coal Co., Ltd.).	Coal . . .	M. L. .	545	12th August 1912.	30 years.
Do. .	(488) Messrs. Shaw, Wallace & Co. (Pench River Coal Company).	Do. . . .	M. L. .	1,511	Do. .	Do.
Do. .	(489) Messrs. Shaw, Wallace & Co. (Central Pench Coal Co., Ltd.).	Do. . . .	M. L. .	1,299	13th August 1912.	Do.
Do. .	(490) Messrs. Shaw, Wallace & Co. (Pench Consolidated Coal Co.).	Do. . .	M. L. .	1,490	Do. .	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chhindwara .	(491) Messrs. Shaw Wallace & Co. (Pench Valley Coal Co., Ltd.).	Manganese . .	M. L. .	929	13th August 1912.	30 years.
Do. .	(492) The Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. (renewal).	58	27th June 1912.	1 year.
Do. .	(493) Do. do. .	Do. . .	P. L. .	159	27th July 1912.	Do.
Do. .	(494) Do. do. .	Do. .	P. L. .	279	Do. .	Do.
Do. .	(495) Do. do. .	Do. . .	P. L. .	115	Do. .	Do.
Do. .	(496) Mr. Byramji Pestonji.	Do. . .	P. L. .	844	13th November 1912.	6 months.
Do. .	(497) Messrs. H. Verma and Kanahyalal.	Coal . . .	E. L. .	5,428	29th November 1912.	1 year.
Jubbulpur .	(498) Mr. M. Gupta .	Soapstone .	P. L. .	163	6th May 1912	Do.
Do. .	(499) Mr. P. C. Dutt .	All minerals .	E. L. .	685	Do. .	Do.
Do. .	(500) Mr. P. C. Dutt and Diwan Bahadur Ballabhdass.	Soapstone and coal	E. L. .	5,454	10th July 1912	Do.
Do. .	(501) Do. do. .	Iron Pyrites .	E. L. .	968	Do. .	Do.
Do. .	(502) Messrs. Turner Morrison & Co.	Barytes . .	P. L. .	576	9th December 1912.	Do.
Nagpur .	(503) Messrs. Lalbihari Narayandass and Ramcharan Shankar Lal.	Manganese . .	P. L. .	224	26th March 1912.	Do.
Do. .	(504) Messrs. Ganeshram Sheoprotap & Sons.	Do. . .	P. L. .	23	Do. .	Do.
Do. .	(505) Mr. P. Balkrishna Naidu.	Do. . .	P. L.	412	23rd March 1912.	Do.
Do. .	(506) Messrs. Radhakisan Brothers.	Do. . .	P. L. .	186	Do. .	Do.
Do. .	(507) Messrs. Lalbihari and Ramcharan.	Do. . .	P. L. .	40	26th March 1912.	Do.
Do. .	(508) Messrs. Radhakisan Brothers.	Do. . .	P. L. .	56	23rd March 1912.	Do.
Do. .	(509) Mr. Madhulal Dugar.	Do. . .	P. L. .	82	12th January 1912.	Do.
Do. .	(510) Messrs. Schröder Smidt & Co.	Do. . .	P. L. .	132	3rd February 1912.	Do.
Do. .	(511) Nagpur Manganese Mining Syndicate.	Do. . .	M. L. .	70	20th February 1912.	5 years.
Do. .	(512) Messrs. Schröder Smidt & Co.	Do. . .	P. L. .	243	3rd February 1912.	1 year.
Do. .	(513) Indian Mineral Mining Syndicate.	Do. . .	P. L. .	22	17th January 1912.	Do.

E. L. = *Exploring License.* P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(514) Mr. A. Hanmant Rao.	Manganese . .	P. L. .	7	29th January 1912.	1 year.
Do. .	(515) Nagpur Manganese Mining Syndicate.	Do. . .	M. L. .	34	17th February 1912.	30 years.
Do. .	(516) Messrs. Schröder Smidt and Company.	Do. . .	P. L. .	106	3rd February 1912.	1 year.
Do. .	(517) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. .	30	9th February 1912.	Do.
Do. .	(518) Messrs. Gancshram Sheopratap and Sons.	Do. .	P. L. .	229	23rd January 1912.	Do.
Do. .	(519) Nagpur Manganese Mining Syndicate.	Do. .	P. L. .	13	9th February 1912.	Do.
Do. .	(520) Do. do. do. .	Do. .	M. L. .	2	19th February 1912.	10 years.
Do. .	(521) Messrs. B. Fauzdar Brothers.	Do. . .	P. L. . (renewal).	46	7th January 1912.	6 months.
Do. .	(522) Messrs. L. R. Ramchandra & Co.	Do. .	P. L. . (renewal).	147	29th January 1912.	1 year.
Do. .	(523) Mr. Lakshman Damodar Lele.	Do. . .	P. L. . (renewal).	12	Do. .	Do.
Do. .	(524) Mr. Byramji Pestonji.	Do. . .	P. L. . (renewal).	97	10th January 1912.	Do.
Do. .	(525) Mr. Lakshman Damodar Lele.	Do. . .	E. L. .	83	26th January 1912.	Do.
Do. .	(526) Messrs. Lalbihari and Ramcharan.	Do. . .	P. L. . (renewal).	38	19th February 1912.	Do.
Do. .	(527) Mr. Mahanandram Sheonarayan.	Do. . .	P. L. .	83	20th May 1912	Do.
Do. .	(528) Central India Mining Company.	Do. . .	P. L. .	96	29th May 1912	Do
Do. .	(529) Mr. Lakshman Damodar Lele.	Do. . .	P. L. .	83	29th May 1912	Do.
Do. .	(530) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. .	40	24th April 1912.	Do.
Do.	(531) Bansilal Abirchand Mining Syndicate.	Do. . . .	M. L.	7	6th May 1912	30 years.
Do. .	(532) Messrs. Schröder Smidt & Co.	Do. . .	P. L.	102	20th May 1912	1 year.
Do. .	(533) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. . (renewal).	93	10th June 1912.	Do.
Do. .	(534) Mr. Lakshman Damodar Lele.	Do. . .	P. L. . (renewal).	52	21st May 1912	Do.
Do. .	(535) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. . (renewal).	143	7th June 1912	Do.
Do. .	(536) Do. do. .	Do. . .	P. L. . (renewal).	255	29th May 1912.	Do.

E. L.—*Exploring License.* P. L.—*Prospecting License.* M. L.—*Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(537) Indian Mineral Mining Syndicate.	Manganese . .	P. L. .	136	8th July 1912	1 year.
Do. .	(538) Carnegie Steel Company.	Wolframite .	M. L. .	120	24th September 1912.	30 years.
Do. .	(539) Mr. A. Hanmant Rao.	Manganese .	M. L.	8	16th September 1912.	Do.
Do. .	(540) Mr. P. Balkrishna Naidu.	Do. . .	P. L. .	156	28th August 1912.	1 year.
Do. .	(541) Mr. Madhulal Dugar.	Do. . .	P. L. .	37	5th August 1912.	Do.
Do. .	(542) Nagpur Manganese Mining Syndicate.	Do. . .	M. L. .	39	23rd August 1912.	15 years.
Do. .	(543) Mr. T. B. Kantharia	Do. .	P. L. .	165	8th July 1912	1 year.
Do. .	(544) Mr. P. Balkrishna Naidu.	Do. . .	P. L. . (renewal).	106	16th May 1912	Do.
Do. .	(545) Do. do. .	Do. . .	P. L. . (renewal).	100	7th June 1912	Do.
Do. .	(546) Messrs. Radha Kisan Brothers.	Do. . .	P. L. . (renewal).	7	4th July 1912	Do.
Do. .	(547) Do. do. .	Do. . .	P. L. . (renewal).	13	11th August 1912.	Do.
Do.	(548) Indian Manganese Company.	Do. . .	P. L. .	31	28th August 1912.	Do.
Do.	(549) Messrs. Sitaram Nathu and Govind Sitaram.	Do. . .	P. L. . (renewal).	359	5th September 1912.	Do.
Do.	(550) Central India Mining Co., Ltd.	Do. . .	P. L. .	448	25th October 1912.	Do.
Do. .	(551) Rai Bahadur Bansilal Abirchand Mining Syndicate.	Do. . .	M. L. .	172	11th October 1912.	26 years—10 months—22 days.
Do. .	(552) Messrs. Lalbehari Naraindas and Ramcharan Shankerlal.	Do. . .	M. L. .	21	17th October 1912.	5 years.
Do. .	(553) Do. do. .	Do. . .	P. L. .	33	18th October 1912.	1 year.
Do. .	(554) Indian Manganese Co., Ltd.	Do. . .	P. L. .	44	23rd November 1912.	Do.
Do. .	(555) Messrs. Radhakisan Brothers.	Do. . .	P. L. . (renewal).	490	16th May 1912	Do.
Do. .	(556) Mr. Lakshman Damodhar Lele.	Do. . .	P. L. .	46	14th December 1912.	Do.
Do. .	(557) Seth Mahanand Ram Sheonarain.	Do. . .	P. L. .	314	30th November 1912.	Do.
Do. .	(558) Indian Mineral Mining Syndicate.	Do. . .	P. L. . (renewal).	192	4th July 1912	Do.

E. L.=*Exploring License.* P. L. = *Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(559) Mr. P. Balkrishna Naidu.	Manganese .	P. L. . (renewal).	467	26th August 1912.	1 year.
Do. .	(560) Sir G. M. Chitnavis, K.C.I.E.	Do. .	P. L. . (renewal).	1,792	14th August 1912.	Do.
Do. .	(561) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. .	114	31st December 1912.	Do.
Do.	(562) Do. do. .	Do. . .	E. L. .	11	Do. .	Do.
Do. .	(563) Do. do. .	Do. . .	P. L. . (renewal).	454	23rd September 1912.	Do.
Do. .	(564) Do. do. .	Do. . .	P. L. . (renewal).	86	25th October 1912.	Do.
Do. .	(565) Do. do. .	Do. . .	E. L. .	62	31st December 1912.	Do.
Do. .	(566) Do. do. .	Do. . .	E. L. .	95	Do. .	Do.
Do. .	(567) Messrs. Balibhadra and Mohanlal.	Do. . .	E. L. .	104	25th October 1912.	Do.
Do. .	(568) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. . (renewal).	71	4th November 1912.	Do.
Do. .	(569) Do. do. .	Do. . .	E. L. .	39	31st December 1912.	Do.
Do. .	(570) Do. do. .	Do. . .	E. L. .	17	Do. .	Do.
Do. .	(571) Do. do. .	Do. . .	E. L. .	35	Do. .	Do.
Do. .	(572) Do. do. .	Do. . .	E. L. .	69	Do. .	Do.
arsingpur .	(573) Dewan Bahadur Ballabhdass & Sons and Mr. P. C. Dutt.	Iron and Coal .	E. L. .	261	2nd September 1912.	Do.
aipur . .	(574) Mr. Byramji Pestonji.	Graphite . .	E. L. .	41	22nd May 1912.	Do.
Do. . .	(575) Mr. T. B. Kantharia.	Do. . .	P. L. . (renewal).	351	14th October 1912.	Do.
augor . .	(576) Messrs. Ganpat Rao Shrikhande, Gopal Rao Shrikhande, Ramkrishna Rao Shrikhande and Damodar Rao Shrikhande, Rao Bahadur.	Iron, Gold, Silver, Copper, Coal and Mineral Oil.	P. L. .	561	20th August 1912.	Do.
Do. . .	(577) Mr. P. C. Dutt and Diwan Bahadur Ballabhdass.	Iron-ore . .	E. L. .	1,104	2nd September 1912.	Do.
Do. . .	(578) Do. do. .	Iron and Copper ores.	E. L. .	1,600	Do. .	Do.
oni . .	(579) Messrs. Schröder Smidt & Co.	Manganese . .	P. L. .	261	2nd February 1912.	Do.

E. L.=*Exploring License.* P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Seoni . .	(580) Messrs. Ratanchand Keshrichand Chullaney & Sons.	Silver and Lead .	P. L. .	284	2nd March 1912.	1 year.
Do. . .	(581) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Manganese .	P. L. .	227	1st April 1912	Do.
Do. . .	(582) Messrs. Khimji Kuverji.	Do. . .	P. L. .	68	29th October 1912.	Do.

MADRAS.

Anantapur .	(583) The Indian Minerals Co., Betamcherla.	All Minerals .	E. L. .	The whole of Gooty and Tedpatri Taluks, exclusive of private patta and inam lands.	13th March 1912.	1 year.
Bellary . .	(584) Mr. A. Ghose, Dhone	Do. . .	E. L. .	Copper mountain ranges.	28th August 1912.	Do.
Chingleput .	(585) James Short, Esq., Madras.	Do. . .	P. L. .	Not stated	9th February 1912.	Do.
Chittoor .	(586) Govindji Odoji Sait, Madras.	Corundum .	P. L. .	45·04 .	27th January 1912.	Do.
Do. .	(587) Do. . . .	Do. . .	P. L. .	16·06	1st March 1912.	Do.
Do. .	(588) Do. . . .	Do. . .	P. L. .	176	14th December 1912.	Do.
Coimbatore .	(589) C. V. Narsaayya, Barrister-at-Law.	Mica . . .	P. L. .	5·91	2nd March 1912.	Do.
Guntur . .	(590) Mr. A. Ghose, Dhone.	All minerals .	E. L. .	Ongole Division.	27th September 1912.	Do.
Do. . .	(591) Mr. C. Jambon, Calcutta.	Diamonds . .	E. L. .	Sattanapalli Taluk.	Do. .	Do.
Kurnool .	(592) Gangaji Rasa of Kurnool.	All minerals .	E. L. .	Whole of Nandikotkur Taluk.	17th February 1912.	Do.
Do. .	(593) A. Ghose, Esq. .	Do. . .	E. L. .	Whole of Pattikonda Taluk.	16th March 1912.	Do.
Do. .	(594) H. Whitney Coates, Esq., of Messrs. Wrenn Bennett & Co., Bangalore.	Diamonds . .	P. L. .	400 acres in S. No. 342-A of Surparajapuram (western portion).	22nd April 1912.	Do.
Do. .	(595) Messrs. Beardsell & Co., Madras.	Barytes . .	P. L. .	5·00 in Betamcherla reserved forest.	2nd July 1912.	Do.

E. L.—*Exploring License.* P. L.—*Prospecting License.* M. L.—*Mining Lease.*

MADRAS—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kurnool .	(596) Messrs. Beardsell & Co., Madras.	Barytes . .	P. L. .	5	2nd July 1912	1 year.
Nellore . .	(597) Sankara Mining Syndicate.	Samarskite .	M. L. .	22·30	30th September 1911.	21 years 10 months 27 days.
Do. . .	(598) K. Penchalu Reddi	Mica . . .	M. L.	155·35	26th August 1911.	30 years.
Do. . .	(599) P. Venkatrama Nayudu.	Do. . . .	P. L. .	10·99	19th August 1911.	1 year.
Do. . .	(600) Lt.-Col. M. E. Reporter.	Do. . . .	M. L. .	44·33	8th January 1912.	30 years
Do. . .	(601) N. Narayana Raju	Do. . . .	M. L. .	96·80	11th September 1911.	Do.
Do. . .	(602) Subramania Chettiyar.	Do. . . .	M. L. .	17·09	5th August 1911.	Do.
Do. . .	(603) R. Lakshminarasa Reddi.	Do. . . .	P. L. .	21·65	6th February 1912.	1 year.
Do. . .	(604) Jatti Balarama Reddi.	Do. . . .	M. L. .	6·26	9th October 1911.	20 years
Do. . .	(605) P. Krishnaswami Mudaliyar.	Do. . .	P. L. .	26·48	10th November 1911.	1 year.
Do. . .	(606) V. Venkatasubbayya Nayudu.	China clay . .	M. L. .	46·52	8th November 1911.	30 years.
Do. . .	(607) P. Krishnaswami Mudaliyar.	Mica . . .	P. L. .	28·70	4th November 1911.	1 year.
Do. . .	(608) Messrs. Haji Muhammad Badsha Sahib & Co.	Do. . . .	P. L. .	36·00	10th January 1912.	Do.
Do. . .	(609) P. Krishnaswami Mudaliyar.	Do. . . .	P. L. .	32·07	1st March 1912.	Do.
Do. . .	(610) G. Chenchu Subba Reddi.	Do. . . .	P. L. .	10·25	21st May 1912	Do.
Do. . .	(611) P. V. Krishna Rao	Do. . . .	P. L. .	19·35	4th March 1912	Do.
Do. . .	(612) G. Nagayya . .	Do. . . .	P. L. .	17·82	28th April 1912.	Do.
Do. . .	(613) George Illgen .	All minerals .	E. L. .	No specified area was given; but permission was granted to explore over reserved and unreserved land.	6th June 1912	Do.
Do. . .	(614) Fred. Cross, Esq. .	Garnet . .	P. L. .	21·40	20th April 1912.	Do.
Do. . .	(615) Masa Abdul Rahiman Sahib.	Mica . . .	M. L. .	34·55	19th March 1912.	30 years.

E. L.—*Exploring License.* P. L.—*Prospecting License.* M. L.—*Mining Lease.*

MADRAS—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore . .	(616) P. Krishnaswami Mudaliyar.	All minerals .	E. L. .	All unoccupied lands.	22nd August 1912.	1 year.
Do. . .	(617) A. Ghose, Esq., Dhone.	Do. .	E. L. .	All unoccupied reserved and unreserved lands in Government villages.	27th September 1912.	Do.
Trichinopoly .	(618) A. Ghose, Esq., Betamcherla.	Do. .	E. L. .	430,720 excluding private patta and Inam lands.	21st May 1912	Do.
Vizagapatam .	(619) Mr. T. R. Lucas, Manager of the Bobbili Mining Co., Ltd.	Manganese . .	M. L. .	7·62	9th March 1912.	30 years.

PUNJAB.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jhelum . .	(620) Lala Thakur Das Ramji Das.	Coal . . .	M. L. .	455	30th October 1910.	30 years.
Kangra .	(621) T. J. Greenall .	Slates . .	E. L. .	2,895·885	8th August 1912.	1 year.
Rawalpindi .	(622) Col. P. H. H. Massy, I. A. (retired).	Mineral oil . .	E. L. .	640	14th August 1912.	Do.

E. L.—*Exploring License*. P. L.—*Prospecting License*. M. L.—*Mining Lease*.

SUMMARY.

PROVINCES.	Prospecting Licenses.	Exploring Licenses.	Mining Leases.	Total of each Province.
Assam	6	..	2	8
Baluchistan	..	..	3	3
Bengal	1	..	..	1
Bihar and Orissa	29	..	8	37
Bombay	1	7	..	8
Burma	319	13	3	335
Central Provinces	113	43	34	190
Madras	18	10	9	37
Punjab	..	2	1	3
Total for each kind and Grand Total, 1912 .	**487**	**75**	**60**	**622**
Totals for 1911	*592*	*99*	*84*	*775*

CLASSIFICATION OF LICENSES AND LEASES.

TABLE 28.—*Prospecting Licenses and Mining Leases granted in Assam during 1912.*

District.	1912. No.	1912. Area in acres.	1912. Mineral.
Prospecting Licenses.			
Khasi and Jaintia Hills	3	16,052·48	Corundum.
Do.	1	7,040	Mineral oil.
Lakhimpur	1	12,800	Coal, oil, slate, shale, iron and other metals exclusive of gold, silver and precious stones.
Nowgong	1	12,800	Coal.
TOTAL	6	..	
Mining Leases.			
Lakhimpur	1	1,280	Coal.
Naga Hills	1	2,728·93	Coal.
TOTAL	2	..	

TABLE 29.—*Mining Leases granted in Baluchistan during 1912.*

District.	1912. No.	1912. Area in acres.	1912. Mineral.
Kalat	2	160	Coal.
Zhob	1	91	Chromite.
TOTAL	3	..	

TABLE 30.—*Prospecting Licenses granted in Bengal during 1912.*

District.	1912.		
	No.	Area in acres.	Mineral.
Chittagong	1	3,671	Mineral oil.
TOTAL	1	..	

TABLE 31.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during 1912.*

District.	1912.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Hazaribagh	20	2,663·24	Mica.
Sambalpur	3	3,547·04	Coal.
Singhbhum	3	3,641·6	Manganese.
Do.	2	1,369·6	Iron-ore.
Do.	1	3,200 (about).	Galena and its associates.
TOTAL	29	..	
Mining Leases.			
Hazaribagh	6	477	Mica.
Singhbhum	2	4,121·6	Iron-ore.
TOTAL	8	..	

TABLE 32.—*Prospecting Licenses granted in Bombay during 1912.*

DISTRICT.	1912.		
	No.	Area in acres.	Mineral.
Panch Mahals . . .	1	156	Manganese.
TOTAL .	1	..	

TABLE 33.—*Prospecting Licenses and Mining Leases granted in Burma during 1912.*

DISTRICT.	1912.		
	No.	Area in Acres.	Mineral.
Prospecting Licenses.			
Amherst	4	6,080	All minerals except oil.
Do.	1	2,240	Wolfram.
Do.	1	2,080	Wolfram, gold, silver and copper.
Do.	1	2,080	Tin, wolfram, gold, silver and copper.
Katha	1	640	Gold, silver, lead, copper and mica.
Do.	1	751·36	Gold, silver, copper, tin and lead.
Do.	2	3,520	Silver and lead.
Do.	1	220	Copper, gold, silver, lead, tin, iron, coal, asbestos and zinc.
Do.	1	2,464	Lead.
Magwe	3	3,520	Petroleum.
Do.	4	6,143	Mineral oil.
Mandalay	1	2,560	Lead and silver.
Mergui	66	156,560·787	All minerals (except oil).
Do.	2	2,191·36	Wolfram, gold, tin and allied metals.
Carried over .	80	..	

TABLE 33.—*Prospecting Licenses and Mining Leases granted in Burma during 1912*—contd.

District.	1911. No.	1911. Area in acres.	1911. Mineral.
Prospecting Licenses—*contd.*			
Brought forward	89	..	
Mergui	1	640	Tin.
Do.	2	6,256·64	Wolfram.
Minbu	13	24,304·94	Petroleum.
Do.	22	26,962·13	Mineral oil.
Myingyan	9	8,049·28	Petroleum.
Do.	6	5,643·35	Mineral oil.
Do.	1	2,560	Wolfram, jasper and precious stones.
Myitkyina	1	640	Copper, silver and Iron.
Do.	2	8,160	Platinum.
Do.	1	7,680	Gold, platinum and minerals of the platinum group.
Northern Shan States	1	960	Lead and allied metals.
Do.	1	3,200	Coal.
Do.	1	960	Galena and allied minerals.
Do.	1	640	Lead, silver and allied minerals.
Do.	1	3,200	Silver, lead, iron and copper.
Pakokku	6	9,146·88	Petroleum.
Do.	5	6,691·49	Mineral oil.
Pegu	1	5,670·46	Gold and tin.
Prome	1	3,200	Petroleum.
Do.	2	8,692·10	Mineral oil.
Sagaing	1	3,190	Petroleum.
Do.	1	9,561·6	Copper ore.
Salween	1	3,200	Gold.
Shwebo	2	6,400	Petroleum.
Southern Shan States	1	160	Gold and silver.
Do.	1	2,560	Tungsten, tin, copper and associated minerals.
Do.	1	640	Gold, silver, copper and lead.
Do.	1	1,547	Gold and associated minerals.
Do.	1	3,200	Coal.
Do.	1	3,200	Gold, copper, tin, and allied minerals.
Carried over	178	..	

TABLE 33.—*Prospecting Licenses and Mining Leases granted in Burma during 1912*—concld.

Prospecting Licenses—*concld.*

District.	1911. No.	Area in acres.	Mineral.
Brought forward .	178	..	
Southern Shan State . .	2	680	All minerals (except oil).
Do. . .	1	400	Silver and lead.
Do. . .	1	3,200	Copper and other minerals (except mineral oil).
Do. . .	1	960	Antimony, lead, silver and tin.
Tavoy	95	215,279·75	All minerals (except oil.)
Do.	3	2,989	Tin, wolfram and allied minerals.
Do.	1	1,216	Wolfram.
Thaton	17	64,249·70	All minerals (except oil.)
Thayetmyo	4	9,080·32	Petroleum.
Do.	9	26,008	Mineral oil.
Do.	1	1,920	Gold.
Toungoo	2	3,200	Gold, silver, tin, iron and wolfram.
Upper Chindwin . . .	3	65,280	Petroleum.
Do. . . .	1	40,960	Coal and other minerals (except oil).
TOTAL .	319	..	

Mining Leases.

District.	No.	Area in acres.	Mineral.
Mandalay	1	66·56	Iron ore.
Myingyan	1	1,920	Mineral oil.
Southern Shan States . .	1	2·1	Lead and silver.
TOTAL .	3	..	

TABLE 34.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1912.*

DISTRICT.	1912.		
	No.	Area in acres.	Mineral.

Prospecting Licenses.

Balaghat	25	3,299	Manganese.
Betul	1	96	Bauxite.
Do.	1	124	Manganese.
Bhandara	11	1,543	Do.
Bilaspur	1	11,623	Coal and iron.
Chhindwara	13	3,633	Manganese.
Do.	1	5,460	Coal.
Jubbulpur	1	163	Soapstone.
Do.	1	576	Barytes.
Nagpur	52	8,873	Manganese.
Raipur	1	351	Graphite.
Saugor	1	561	Iron, gold, silver, copper, coal and mineral oil.
Seoni	3	556	Manganese.
Do.	1	284	Silver and lead.
TOTAL	113	..	

Mining Leases.

Balaghat	14	1,791	Manganese.
Do.	1	171	Mica.
Betul	1	1,032	Coal.
Bhandara	2	67	Manganese.
Chhindwara	6	11,515	Coal.
Do.	1	929	Manganese.
Nagpur	8	353	Do.
Do.	1	120	Wolfram.
TOTAL	34	..	

TABLE 35.—*Prospecting Licenses and Mining Leases granted in Madras during 1912.*

DISTRICT.	1912.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Chingleput	1	Not stated	All minerals.
Chittoor	3	237·10	Corundum.
Coimbatore	1	5·91	Mica.
Kurnool	1	400	Diamonds.
Do.	1	5	Barytes.
Do.	1	5	Do.
Nellore	9	203·31	Mica.
Do.	1	21·40	Garnet.
TOTAL	18	..	
Mining Leases.			
Nellore	1	22·30	Samarskite.
Do.	6	355·28	Mica.
Do.	1	46·52	China clay.
Vizagapatam	1	7·62	Manganese.
TOTAL	9	..	

TABLE 36.—*Mining Leases granted in the Punjab during 1912.*

DISTRICT.	1912.		
	No.	Area in Acres.	Mineral.
Jhelum	1	455	Coal.
TOTAL	1	..	

NOTES ON THE RELATIONSHIP OF THE HIMALAYA TO THE INDO-GANGETIC PLAIN AND THE INDIAN PENINSULA. BY H. H. HAYDEN, C.I.E., *Director, Geological Survey of India.*[1] (With Plates 3 and 4.)

One of the most striking features of the Himalayan mountain system is the great series of transverse ridges which can be traced from end to end along its outer margin and constitutes the Lesser Himalaya. Standing on the heights above one of the Himalayan hill-stations and looking along the range, the observer sees ridge after ridge, all of approximately the same height and each separated from the other by a deep, yet comparatively flat-bottomed, valley many thousand feet below the crest of the ridge. A very marked characteristic of this topography is the uniformity of height of the long straight ridges, and it is impossible to resist the impression that they are merely the relics of a deeply eroded peneplain, an impression which becomes conviction when one sees a model of a representative part of the mountain system. Such a model has recently been constructed by Major M. O'C. Tandy, R.E., of the Survey of India, who has reproduced on a horizontal scale of 16 miles=1·014 inch and a vertical scale 8½ times as large, the Himalayan region of Kumaun and Garhwal and to whom I am indebted for permission to reproduce the accompanying photograph (Plate 3, fig. 1). On the south-west is the gently sloping plain of the Gangetic alluvium passing into billowy ridges of the Siwalik hills; these stand as outworks in front of the great Himalayan wall which rises sheer and abrupt from the open 'duns' at its foot. The wall is but the edge of a shelf which extends all along the Himalaya and across them as far as the line of high snowy peaks, where again a second abrupt wall rises,—the outer wall of the central granitic core. Beyond the latter we reach the fossiliferous sedimentary zone belonging to the geosynclinal of the Tethys; but with this we are now only incidentally concerned and our chief interest centres round the peneplain of the Lesser Himalaya, the component rocks of which consist

[1] I am indebted to all my colleagues of the Geological Survey Department, and especially to Mr. C. S. Middlemiss, for much valuable criticism of this note before it was sent to press.

primarily of the members of the Carbonaceous system, with its various supposed representatives, and the Sirmur series, which, however, forms only the outer fringe of the broad peneplain.

Many attempts have been made to find the correct position of the Carbonaceous system in the geological scale, but none is yet entirely convincing. For a considerable period the assumed identity of the Blaini boulder-bed with that of the Talchir series was accepted as evidence of an Upper Carboniferous or Permian age for the Blaini series and the Carbonaceous slates and a Triassic for the overlying limestone of the Krol mountain. So far as lithological characters go there is much to be said for this correlation in view of the marked resemblance of Blaini boulder-bed to Talchir, whilst the so-called "Bleach slates," which overlie the boulder-bed, are extraordinarily like the Gangamopteris beds of Kashmir. At the same time an almost equally good case can be made out on lithological grounds for correlation with the Haimanta and Muth systems of Spiti. On the other hand the apparently complete absence of fossils throughout this broad zone of the Himalaya makes it difficult to believe that it belongs to any of the recognised post-Purana systems. It has been suggested by a writer in *Nature* (vol. LXXXI, (1909), p. 425) that the Carbonaceous system may represent a flysch facies of the systems of Spiti. Its thickness, with the Simla slates and Shali limestone, is many thousand—perhaps 10,000—feet, or about equivalent to the whole of the Palaeozoic (including Haimanta), or to the whole of the Mesozoic and Tertiary strata as developed in the higher Himalaya of Spiti and Kumaun; a large part of this suggested flysch series consists of fine-grained limestone—Shali, Deoban, Krol—, which cannot with any show of probability be regarded as of other than normal marine origin; there is consequently no reason to suppose that the Carbonaceous system represents merely a short phase in geological history and it does not seem probable that marine organisms with hard parts should have been entirely absent for such vast periods from any sea that may have covered this area while present in great numbers in the adjoining basin. The flysch hypothesis has in fact already been carefully examined and rejected[1] and there is no apparent reason for its revival. The Shali limestone, which has been correlated by Oldham with that of the

Relationship of unfossiliferous series to the Purana system.

[1] T. H. Holland; *Rec. Geol. Surv. India.*, vol. XXXVII (1908), p. 132,

Deoban hill, is a compact, fine-grained, cryptocrystalline rock often perfectly homogeneous, but at times containing masses of flint and small spherical grains. No trace of recognisable organisms has been discovered either in the Shali or in the Deoban limestone, although on the Mashobra-Naldera ridge near Simla the Shali limestone at first sight appears to be highly fossiliferous and resembles a Fusulina limestone; closer examination, however, proves the peculiar appearance to be merely the result of brecciation, the rock consisting of comminuted fragments, some of which are dark grey or black and others reddish brown. [1]

The Krol limestone, as Medlicott pointed out, resembles that of the Shali in many respects; stratigraphically, however, the latter appears to be very much the older and is usually regarded as older than the Infra-Blaini beds (Simla slates) and as the equivalent in age of the limestone of the Deoban peak. Whether the Shali and Krol limestones be of the same age or not is immaterial to the present purpose, which is to draw attention to the amount of disturbance that all these old Himalayan formations have undergone and which differentiates them at once from the fossiliferous rocks associated with them in the outer part of the range as well as from the deposits of the Tethys basin in the interior of the higher Himalaya. The Simla region affords instructive examples of this contrast; from the Shali peak to the Barogh ridge, cliffs and roadside cuttings display every variety of fold and fault; inversion and overthrust are conspicuous, the most familiar and accessible examples being seen on the Mahasu ridge and along the Simla-Mashobra road. On the Barogh ridge the two groups are in contact along the Barogh fault and the contrast on either side is well marked. On the one side are the contorted and metamorphosed slates and siliceous limestones of the Carbonaceous system, on the other the disturbed, but unaltered, shales and sandstones of the Sirmur series. The difference in degree of disturbance is as striking as the difference in degree of metamorphism. The Tertiary beds have certainly passed through a phase of considerable folding and faulting, but the effects of this are as nothing in comparison with the effects of the tectonic history of the Carbonaceous system, which appears to have passed through not one but many periods of folding equally intense.

[1] I am indebted to my colleague, Mr. G. H. Tipper, for the confirmation of my observations in this respect.

If the Carbonaceous system be in reality merely a flysch facies of part or of the whole of the fossiliferous systems of the Tethys basin, it should not show any markedly greater degree of disturbance or metamorphism than is to be found in the rocks of the Sirmur series, since we know that the neighbouring portions of the Tethys basin were practically undisturbed from the beginning of the Permian until after the end of the eocene period, while the Aryo-Dravidian (Carbo-Permian) disturbance has had no perceptible effect on the physical condition of the post-Purana (Cambrian and younger) sediments except in Kashmir, where volcanic activity—as represented by the Panjal trap—produced local metamorphism, which, however, did not result in the general obliteration of all organic remains from the pre-existing fossiliferous sediments. The present condition of the Carbonaceous system cannot therefore be reasonably ascribed entirely to post-Cambrian regional metamorphism. As regards the case for contact-metamorphism, igneous rocks, both intrusive and extrusive, are known to occur in various places along the Lesser Himalaya; extensive areas on the other hand are apparently free from them, but the rocks are none the less metamorphosed. There is in fact no reason to ascribe any greater obliterating effect to contact-metamorphism in this zone than in the fossiliferous Tibetan zone of Kumaun, Spiti and Kashmir, and in spite of the lithological resemblance between Blaini and Talchir, the apparently complete absence of all trace of fossils from the whole Carbonaceous system compels correlation with the lithologically similar members of the Purana group of the Peninsula. Just as the one set of rocks extends throughout almost the whole length of the Himalaya, so the other extends across almost the whole Peninsula and it requires no great stretch of the imagination to carry the Vindhyan mass of Central India northwards across the Gangetic alluvium into the mountains of Nepal and Garhwal. The presence of Gondwanas in the Eastern Himalaya on the one side and in Kashmir on the other proves that the alluvium now covers part of Gondwanaland, which, having reached the eastern and the western, may with propriety be expected to have extended also into the central parts of the Himalaya. There seems, therefore, to be some justification for regarding the Lesser Himalaya as originally part of the Gondwana continent from which they subsequently became detached by tectonic disturbances.

The Lesser Himalaya part of Gondwanaland.

The manner in which this severance occurred and the character of the depression underlying the Indo-Gangetic alluvium are matters which are now receiving a considerable amount of attention in consequence of the geodetic results obtained during recent years by the officers of the Survey of India.

The Indo-Gangetic depression and postulated sub-crustal crack.

The most recent contribution to this subject is a paper by Colonel S. G. Burrard, Surveyor-General of India, "On the Origin of the Himalaya Mountains"[1], in which he discards previously accepted hypotheses on the ground of geodetic inadequacy and puts forward the interesting and ingenious hypothesis that the Indo-Gangetic depression is a great "sub-crustal" crack or rift extending from the surface far down into the crust—twenty miles in the only case in which a definite figure is given—and filled with alluvium. The chief ground on which Colonel Burrard bases this assumption is the rapid decrease in the amount of deflection of the plumb-line at three groups of stations at and near the foot of the Himalaya, *viz.*, Kurseong-Siliguri-Jalpaiguri (25 miles),[2] Birond-Nimkar (112 miles) and Dehra Dun-Kaliana (56 miles).

Anomalies in the local deflections of the plumb line.

For the benefit of those students of Indian geology who have not made a detailed study of the geodetic aspects of the Himalayan problem, it may be advisable to give a brief outline of the causes leading up to the formulation of this hypothesis. Colonel Burrard who, by researches extending over a long period of years, has made the subject peculiarly his own, has defined the plumb-line as "a string hanging under the influence of gravity. A cord stretched by a hanging weight is forced to assume a vertical position by the attraction of the earth upon the weight, but if a mountain is situated on one side and a flat plain on the other, the plumb-line does not coincide with the normal to the spheroidal surface of the earth, but is deflected towards the excess of mass. If the crust of the earth were homogeneous, and if no mountains nor hollows existed at the surface, the plumb-line would everywhere coincide with the normal"[3]. But since the crust is not homogeneous and since its surface is uneven, it is frequently found that the plumb-line, instead of coinciding with the normal, is more

[1] *Survey of India, Professional Paper* No. 12 (1912).
[2] Meridional distance from Kurseong to Jalpaiguri.
[3] *Geography and Geology of the Himalaya and Tibet* (1907), p. 51.

or less strongly deflected in one direction or another, usually towards some visible excess of material. To this, however, there are exceptions and about the middle of last century it was found from observations made by members of the Survey of India that at Kaliana, which is only some fifty miles from the foot of the Himalaya and where the northerly deflection due to their attraction ought theoretically to be 58", the mountains have apparently no effect on the plumb-line, the direction of which there practically coincides with the normal. Similar results have been obtained at other stations along the foot of the Himalaya, and it has been found that the actual amount of deflection of the plumb-line is invariably considerably less than it would be if all topographic features exerted the full measure of attraction due to their apparent mass. This fact long puzzled geodesists, but it was eventually suggested by Archdeacon Pratt that the anomalies were due to "compensation"[1] of the mountain masses, the attractive effect of the latter being counteracted by deficiency in density of the material underlying them. This became known as the hypothesis of "mountain compensation."

Mountain compensation.

As observations were extended, however, it was found that this hypothesis was apparently indequate to meet all cases; although compensation might account for the absence of attraction at Kaliana, it did not seem able to explain the rapid decrease in the amount of attraction between, say, Dehra Dun and Kaliana; at the former station the northerly deflection of the plumb-line is 31", whereas at Kaliana it is only 1". If the Himalaya were uncompensated and if the decreases in deflection were due to the greater distances of Kaliana, Nimkar and Jalpaiguri respectively from the mountain foot, these figures should be only 28", 30" and 26"; the apparent decrease in the attractive effect of the mountains is therefore abnormally rapid. A correspondingly rapid rate of decrease was observed along other lines such as those already mentioned above (p. 142), the decrease between Birond and Nimkar being 13" and between Kurseong and Jalpaiguri 45".

These and further researches led to the conclusion that the attraction of the Himalaya was being counterbalanced by an attrac-

[1] *Phil. Trans., Royal Society*, vol. 149 (1859), p. 745. The idea of compensation actually originated with Sir George Airy (*Phil. Trans., vol.* 145 (1855), p. 100) and was adopted and modified by Pratt.

tion in the opposite direction and that the cause of the rapid rate of decrease of the northerly deflection was "that an invisible chain of excessive density, parallel with the Himalaya, is underlying the plains of Northern India: this buried chain is 150 miles distant from the foot of the mountains; at stations like Kaliana the southerly attraction of this chain is counteracting the northerly attraction of the Himalaya; at Dehra Dun, where the Himalaya are near and the buried chain is distant, the effect of the latter is not very apparent, but as we move southwards, the attraction of the visible mountains to the north decreases, and that of the invisible mass to the south increases. The suddenness with which deflections of the plumb-line decrease as we recede from the Himalaya is due to the presence of a southerly and subterranean source of opposite attraction."[1] The presence of this belt of high density has been confirmed by the results of the pendulum operations.

The line of high density.

In the year 1889 the idea of mountain compensation was brought prominently forward by Major C. E. Dutton, who embodied it in his now well-known hypothesis of *isostasy*[2], which has recently been established on a basis of great precision by J. F. Hayford, W. Bowie and other members of the Coast and Geodetic Survey of the United States[3]; this hypothesis has been enunciated very clearly by Hayford and I cannot do better than quote his words:—

Isostasy.

"If the earth were composed of homogeneous material, its figure of equilibrium, under the influence of gravity and its own rotation, would be an ellipsoid of revolution.

The earth is composed of heterogeneous material which varies considerably in density. If this heterogeneous material were so arranged that its density at any point depended simply upon the depth of that point below the surface, or, more accurately, if all the material lying at each equipotential surface (rotation considered) was of one density, a state of equilibrium would exist and there would be no tendency toward a rearrangement of masses.

If the heterogeneous material composing the earth were not arranged in this manner at the outset, the stresses produced by gravity would tend

[1] *Geography and Geology of the Himalaya Mountains and Tibet*, p. 53. See also S. G. Burrard: *Survey of India, Prof. Paper* No. 5 (1901), p. 107.

[2] *Bull. Phil. Soc. Washington*, vol. XI, p. 51.

[3] "The figure of the Earth and Isostasy" (1909); "Supplementary Investigation in 1909 of the Figure of the Earth and Isostasy" (1910); "The Effect of Topography and Isostatic Compensation on the Intensity of Gravity" (1912), in collaboration with W. Bowie. *U. S. Coast and Geodetic Survey.*

to bring about such an arrangement; but as the material is not a perfect fluid, as it possesses considerable viscosity, at least near the surface, the rearrangement will be imperfect. In the partial rearrangement some stresses will still remain, different portions of the same horizontal stratum may have somewhat different densities, and the actual surface of the earth will be a slight departure from the ellipsoid of revolution in the sense that above each region of deficient density there will be a bulge or bump on the ellipsoid, and above each region of excessive density there will be a hollow, relatively speaking. The bumps on this supposed earth will be the mountains, the plateaus, the continents; and the hollows will be the oceans. The excess of material represented by that portion of the continent which is above sea level will be compensated for by a defect of density in the underlying material. The continents will be floated, so to speak, because they are composed of relatively light material; and, similarly, the floor of the ocean will, on this supposed earth, be depressed because it is composed of unusually dense material. This particular condition of approximate equilibrium has been given the name isostasy.

The adjustment of the material toward this condition, which is produced in nature by the stresses due to gravity, may be called the isostatic adjustment.

The compensation of the excess of matter at the surface (continents) by the defect of density below, and of surface defect of matter (oceans) by excess of density below, may be called the isostatic compensation.

Let the depth within which the isostatic compensation is complete be called the depth of compensation. At and below this depth the condition as to stress of any element of mass is isostatic; that is, any element of mass is subject to equal pressure from all directions as if it were a portion of a perfect fluid. Above this depth, on the other hand, each element of mass is subject in general to different pressures in different directions—to stresses which tend to distort it and to move it."[1]

Depth of isostatic compensation:

Working on this basis Hayford has shown that if it be assumed that all surface features, whether elevations or depressions, be compensated by reason of defective or excessive density of the underlying material and that if such *isostatic compensation* be complete at a depth of 113·7 kilometres (subsequently modified to 122 km = 76 miles), the anomalies between the observed and computed values for the deflection of the vertical, as measured by the plumb-line, throughout the United States become comparatively insignificant.

In the United States;

In India.

An attempt to apply the same principles to India has shown that the discrepancies, especially in the Himalaya and at stations on the Indo-Gangetic alluvium, are much greater than those found in America. The

[1] The Figure of the Earth and Isostasy (1909), p. 66.

conditions which contribute to bring about these and other geodetic anomalies may, as we have seen, belong to three classes:

(*a*) complete or partial compensation of the surface features, by modifications of density of the subjacent material extending down to some, at present unspecified, depth;

(*b*) the presence of a belt of material of high density crossing India on the south of the Indo-Gangetic alluvium;

(*c*) the presence of a belt of low density—the Indo-Gangetic alluvium—consisting of a trough filled with material having a lower specific gravity than that of the average material composing the superficial crust of the earth.

At stations between the Himalaya and the belt of high density, the effect of (*a*) will be to reduce the attractive force of the Himalaya, of (*b*) to exert a greater amount of attraction than would be expected from the surface features, and of (*c*) to intensify the effect of (*b*) owing to deficient density and consequent failure to exert a normal amount of attraction.

Colonel Burrard's recent paper on the origin of the Himalaya is designed to show that the observed geodetic anomalies are due to the fact that the belt of low density is not merely, as is generally believed, a simple alluvium-filled trough, shallow on the south and south-west and slowly but steadily deepening towards the mountain foot, but an immense rift, stretching for two thousand miles along the foot of, and beneath, the Himalaya, many miles deep and filled with alluvium.

Nature of the Indo-Gangetic trough.

Before rejecting the hitherto accepted hypothesis in favour of that now put forward by Colonel Burrard, it is desirable to examine the latter with reference to its bearings on sciences other than geodesy. The view generally accepted of the nature of the depression in which the Indo-Gangetic alluvium lies is that it is a "fore-deep" between the wave-front of the Himalayan system of folding and the horst of Gondwanaland (Suess) [1] as now represented for the greater part by the Indian Peninsula, and produced by the elevation of the mountain range with concomitant sinking, partly original and partly due to subsequent overloading, of the submontane tracts (Fisher, Oldham)[2]. Another possibility is to regard

[1] E. Suess: *The Face of the Earth*, vol. IV, pp. 612, 627.
[2] *Manual of the Geology of India*, 2nd edition (1895), p. 471.

the depression as a true trough-fault, similar to the Great Rift Valley of Africa [1] or to the *Grabeneinsenkungen* of the Rhine, and probably coeval in origin with the break-up of Gondwanaland. The steep wall of the Western Ghats and the sudden deepening of the Arabian Sea not far from its northern and western shores point to the probability that that sea occupies a basin of subsidence; a similar origin has been ascribed to the basin of the Red Sea [2]. At the same time the floor of the Bay of Bengal also falls away rapidly from its western shores, and the Indian peninsula certainly has the appearance of a fragment left standing while the adjacent areas subsided;[3] and, like the waters of the adjacent seas, the Indo-Gangetic alluvium may fill a trough produced by subsidence during the breaking up of the pre-existing continent. In that case a fragment of Gondwanaland, represented by the Gondwanas of Kashmir and the Carbonaceous system on the west, and the Daling, Baxa and Gondwana beds on the east, would have been cut off from the main mass of the Peninsula, thus blocking out what is now the Lesser Himalaya and forming the southern shore of the Tethys.

Whichever of these views we take we are confronted with the presence, along the foot of the Himalaya, of a series of reversed faults, parallel to the trend of the mountains and separating the older rocks from the younger and from the area now covered by the Indo-Gangetic alluvium. These faults are ascribed by Fisher and Oldham to movements resulting from isostatic readjustment due to transference of material from the Himalaya to the plains at their foot. From this point of view, which is that generally adopted, the reversed faults become overthrusts.[4] Colonel Burrard on the other hand regards them as due to underthrust acting towards the north and attributable (1) to the opening of a crack or

[1] J. W. Gregory: *The Great Rift Valley* (1896).

[2] Suess: *op. cit.*, vol. I, p. 274, vol. IV, p. 277; W. F. Hume: The Topography and Geology of the Peninsula of Sinai; *Survey Dept., Egypt* (1906), p. 36. Recently Dr. Ball has stated that this view is erroneous and that the Red Sea is in reality a drowned valley (The Geography and Geology of S. E. Egypt: *Survey Dept., Egypt* (1912), p. 355).

[3] E. Suess: *id.*, vol. II, p. 537.

[4] My colleague, Mr. E. H. Pascoe, has drawn my attention to the fact that the form of curvature of the mountains all round India seems to indicate that their origin is due to pressure coming from the north or north-east in the case of the Himalayan, and from the ~~west~~ east in the case of the Arakan-Patkoi, arcs. He points out that this is especially noticeable if the strike of the component rocks be studied in conjunction with the apparent trend of the ranges, and that the two arcs cited seem to offer clear evidence of movement towards the Peninsula in each case.

cracks in "sub-crustal shells", (2) to the contraction of the "sub-crust" on the north of the crack or cracks, with (3) consequent wrinkling of the overlying "upper crust."

Conditions prevailing in the postulated rift.

In considering these suggested phenomena, it is desirable first of all to attach a definite meaning to the terms "upper crust" and "sub-crust". As the rift, in opening towards the north, is said to "have crumpled up the thin superficial carpet of sediment into the Himalayas", we may perhaps assume that the thickness of the "upper-crust" is represented by at least the sediments of the Tethys. The thickness of the sedimentary series from Haimanta to eocene as measured in the Himalaya is approximately 20,000 feet or a little less than four miles; if we add to this a similar amount for the older rocks, we arrive at a thickness of eight miles for the "superficial carpet of sediment" or "upper-crust." A safe maximum would probably be ten miles. Consequently the "sub-crust" will presumably extend from not more than ten miles below the surface to a depth not specified. It is this "sub-crust" that is assumed to have cracked. It is further postulated that the crack or rift, which is regarded as filled with alluvium, extended to the surface. This rift is regarded as "sufficiently large to have disturbed the isostatic equilibrium of the crust over a vast area in Southern Asia" (*op. cit., p.* 14), and must therefore have been of very considerable dimensions; definite figures are not available but from the fact that the geodetic anomalies would in one case be satisfied by "a rift in the sub-crust south of Mussoorce and 20 miles deep", the rift would therefore have extended presumably through at least a vertical depth of ten miles below a sedimentary "upper-crust"; it would consequently have passed into a zone of metamorphic rocks and perhaps even through this into a plutonic zone.

The suggestion that mountain compensation might be due to "vast cavities under great mountain masses" appears to have originated with Colonel A. R. Clarke (*Geodesy* (1880), p. 351), who, however, rejected it as "too bold a speculation". In adopting such an hypothesis we should be confronted with many difficulties. In the first place it is very doubtful if such cavities could remain open. F. D. Adams and L. V. King[1] have recently shown experimentally that *small* cavities existing under the conditions of temperature and pressure likely to prevail at considerable depths would

[1] *Journal of Geology*, Vol. XX, No. 2 (1912), pp. 97-138.

remain open at least for some time; these results, however, relate only to very small cavities and cannot be extended to cover tectonic phenomena of the type involved in the elevation of the Himalaya. It has been shown that small (·05 inch) cylindrical cavities in granite are unaffected after a period of 70 hours at a pressure corresponding to a depth of fifteen miles and a temperature corresponding to a depth of eleven or that such cavities occurring in granite at a depth of 11 miles below the surface would remain open for a period exceeding 70 hours. It was further found that at pressures corresponding to a depth of 25 miles such cavities remained open for 2½ months if the temperature was not raised above that of the surface, but under the same conditions broke down at a pressure corresponding to a depth of 35 miles; to extend the results of these experiments made on extremely small cavaities and lasting for only 2½ months to the conditions prevailing in an immense rift extending to a depth of twenty miles below the surface and to forces acting for vast periods would not be justifiable; and when we find the crystalline rocks of Kolar at depths of less than a mile below the surface undergoing perpetual disruption[1] owing to the strain to which they are subject the possibility of the persistence of large cavities at depths ten and twenty times as great seems very remote and until it has been shown that the accepted hypotheses are inadequate to explain the geodetic anomalies, it seems dangerous to postulate the occurrence of a tectonic phenomenon which has no known parallel in the geological history of the earth. There would seem to be no reason why cracks of the kind suggested could not have occurred as well before as after the beginning of the Tertiary period and we might expect to find among the older geological formations traces of such rifts filled with detrital material. Rifts and cracks no doubt are not uncommon and are represented by the familiar trough-fault and the mineral lode, but there is no record of their having taken the form of gaping fissures many miles deep and presumably several miles wide, and subsequently infilled with detrital matter. In the present instance the infilling must in one place at least have a thickness of twenty miles or over 100,000 feet, a thickness about half as great as the

[1] These disruptions are locally but incorrectly known as "air-blasts". In the year 1911 a seismograph installed at the mines registered over 5,000 of these disturbances in three months and it was subsequently found that this figure was considerably too low. *Report of Chief Inspector of Mines, Mysore, for 1911-12 (1913), p. 39.*)

maximum assigned to the whole geological record[1] from Cambrian to Tertiary both inclusive and far greater than that of the corresponding record in India. Other difficulties arise with regard to the lower part—say the lower half—of this postulated deposit; as already pointed out this would extend down through a zone of metamorphic rocks; it would be subject to temperatures ranging from 500°C. to 1,000°C. and to pressures of between 64,100 and 96,000 lbs. per square inch.[2] If we accept the conclusions arrived at by Messrs. Adams and King that the figures given by Van Hise[3] for the depth of the zone of flowage are too small, it is nevertheless evident from the latter's work that the alteration of sediments under the above conditions of pressure and temperature would be considerable and would result, amongst other phenomena, in at least partial recrystallisation; the lower layers might be expected to approximate in specific gravity to metamorphosed sediments rather than to alluvium and would not therefore contribute to the required reduction of density along the line of the postulated rift.

Other objections, based on general principles as well as arising from considerations more particularly connected with local conditions, will no doubt occur to most of those who have made any close study of the geological and tectonic history of the Himalaya, and it would seem inadvisable at present to discard the older theories which have been gradually built up by patient observation and prolonged study in the field by such men as Medlicott, Oldham and Middlemiss—names unrivalled in the field of Himalayan tectonic geology—, and confirmed by the deductive work of Suess and Fisher, based on dispassionate analysis of recorded phenomena.[4]

Before admitting that the generally accepted hopythesis as to the nature of the Indo-Gangetic trough does not adequately explain the apparent geodetic anomalies derived from observations of the deflection of the vertical and the intensity of gravity at stations

[1] W. J. Sollas: Presidental Address, Geological Society, 1909, p. cxii.

[2] These figures for pressure are taken from Table II, (p. 111) of the paper by F. D. Adams already referred to.

[3] *Treatise on Metamorphism.*

[4] Since the above was written some correspondence on the subject of Colonel Burrard's hypothesis has been published in *Nature* (May 8th and May 15th, 1913). In a letter, dated March 29th, (*Nature*, no. 2271, vol. 91, p. 242), Colonel Burrard refers to the "swatch of no ground" at the head of the Bay of Bengal, as well as to that near the mouth of the Indus, as surface indications of a sub-crustal crack. This extension of his rift hypothesis seems to add to the difficulties in the way of accepting it, since the effect of this particular sub-crustal crack must be quite different to that of the crack beneath the alluvium; the plumb-line, instead of being deflected away from, is strongly deflected towards, the "swatch of no ground" in the Bay of Bengal.

in the Himalaya and at others on the alluvium at their foot, the question seems to call for fuller treatment than it has hitherto received. In the following notes an attempt has been made to deal with one—admittedly but a small—aspect of the case, but the results point to the desirability of further application and investigation of the great store of observations collected in the volumes of the "Operations of the Great Trignometrical Survey of India" and other reports of the same Department.

In his interesting paper on the origin of the Himalaya, Colonel Burrard has pointed out with great lucidity the remarkable differences not only between the observed deflections of the plumb-line and the deflections that would be produced by the orographic features—"topographic" deflections—in the absence of any compensation, but also between the observed deflections and the figures obtained by applying to the computed topographic deflections certain corrections based on the assumption—made with such conspicuous success by Hayford in the case of the United States—that the topographic inequalities are essentially compensated by means of subjacent modifications of density and that such compensation is complete at a depth 113·7 kilometres. The data for a large number of stations in India were deduced on this hypothesis by Major H. L. Crosthwait, R.E., of the Survey of India, who came to the conclusion that his results were far less satisfactory for India than were those of Hayford for the United States[1] but that this might be due to the fact that while "the attainment of (isostatic) equilibrium is already far advanced in America, in India it is still in an immature state and compensation is by no means so perfect." In support of this view Major Crosthwait very aptly draws attention to the fact that the Himalayan stage of mountain-building is of comparatively recent date and that equilibrium of the crust in that region might therefore be expected to be still somewhat unstable.

This at once suggests that if the conditions of equilibrium in India are different from those in America there is no valid reason for the tacit assumption that, in a heterogeneous body like the earth, isostatic compensation will occur at the same depth everywhere. Clearly therefore before assuming that isostatic compensation is complete at a depth of 113.7 km. and that some

Depth of complete isostatic compensation in India.

[1] Investigation of the theory of Isostasy in India; *Survey of India, Professional Paper* no. 13 (1912).

special explanation must be sought for the apparent geodetic anomalies arising therefrom, it is advisable to enquire how far these anomalies will be affected by the assumption of compensation occurring at some other depth. In order to do this it is necessary to apply suitable corrections to the topographic deflections. Major Crosthwait has —with an amount of labour that can be appreciated only by those who have actually undertaken similar calculations—determined for a large number of stations the deflections due to all topographic features within a distance of 2,564 miles from each station, and I have been enabled, by the courtesy of Colonel G P. Lenox Conyngham, R.E., Superintendent of the Trigonometrical Survey,—to whom I am greatly indebted also for valuable assistance and advice—to obtain the detailed figures for certain stations. I have applied to these the necessary corrections arising from the assumption of compensation occurring at a number of different depths. The methods employed by Hayford and by Crosthwait have been followed and need not be detailed here, since they can be studied in the original publications. The depths selected ranged from 55.92 kilometres to 1,000 km. and included 77·96, 113·7, 120·9, 162·2, 250, 300, 329·8, 350, 600 and 650 kilometres. Some of these figures were chosen on account of the fact that the correction-factors to be applied to the topographic deflections had already been determined by Hayford and were ready to hand; where, however, the factors were not already available, as for instance in the cases of 250, 300, 350, 600, 650 and 1,000 km., they were deduced from Hayford's curve (*Isostasy and the figure of the Earth* (1909), plate 15). The annexed table shows the results of the application of this principle to all the Himalayan stations for which detailed figures were available. The table is restricted, to deflections in the meridian, since only in a very few cases are topographic figures available in connection with deflections in the prime vertical.

TABLE 1.—*Deflections in the meridian at stations in the Himalaya.*

1		2	3	4	5	6	7	8	9	10	11	12	13
STATION.		Observed Deflection.	Topographic Deflection.	ASSUMED DEPTH OF COMPENSATION.									
				113·7 km.		162·2 km.		250 km.		329·8 km.		600 km.	
G. T. S. No.	Name.	A—G	D	D_c	(A—G) $-D_c$=R	D_c	R	D_c	R	D_c	R	Dc	R
		″	″	″	″	″	″	″	″	″	″	″	″
183	Lambatach	−27	−71	−9·4	−17·6	−13·20	−13·80	−18·78	−8·22	−28·28	+ 1·28	−32·48	+5·48
68	Mussoorie	−30	−86	−17·4	−12·6	−22·29	−7·71	−29·04	−0·06	−33·73	+ 3·73	−44·80	+14·80
18	Dehra Dun	−31	−86	−17·9	−13·1	−22·60	−8·40	−29·14	−0·86	−33·89	+ 2·89	−44·55	+13·55
133	Birond	−38	−74	−14·3	−23·7	−18·31	−19·69	−24·67	−13·33	−27·95	−10·05	−36·67	−1·33
181	Kurseong	−46	−103	−22·7	−23·3	−28·47	−17·53	−36·27	−9·73	−40·93	−5·07	−53·60	+7·6 0
67	Murree	−12	−45	−10	−2	−12·10	+ 0·10	−15·41	+ 3·41	−18·06	+ 6·06	−23·25	+11·25
	AVERAGE .	*−30·67*			*−15·40*		*−11·20*		*−4·80*		*−0·19*		*+ 8·56*

Depth of compensation under the Himalaya.

Against each station is shown first (column 2) the observed deflection in the meridian; this is represented by the difference between the astronomic latitude and the geodetic, A—G, as given by Crosthwait in column 6 of his tables (*op. cit.*, p. 9). The values deduced from the Clarke-Bessel spheroid have been taken since that is the form officially adopted by the Survey of India.[1] The next column shows the topographic deflection as determined by Crosthwait by means of the system of rings and compartments (*op. cit.*, pp. 1, 2). Column 4 shows the result of applying the correction for compensation to the topographic deflection on the assumption that complete isostatic compensation occurs at a depth of 113·7 km.; column 5 shows the discrepancy, or residual (R), between the deflection so computed and the actual deflection observed. Columns 6 and 7, 8 and 9, 10 and 11, 12 and 13, correspond respectively with columns 4 and 5, and represent the computed deflections and their discrepancies according to the varying depths at which compensation is assumed to be complete. The sign of the deflection is based on the usual convention by which northerly deflections are shown as negative and southerly deflections as positive.

If now we analyse the above table we find that if isostatic compensation were complete at a depth of 250 kilometres under Dehra Dun and Mussoorie, the discrepancies between the observed and computed deflections respectively at those stations would to all intents and purposes vanish; but there would still be discrepancies between the observed and calculated values for other stations. Each of these, however, might be regarded as having a critical depth of compensation at which its local anomaly would disappear; thus, if complete isostatic compensation occurred at a depth of about 160 km. below Murree, of 300 km. below Lambatach, of perhaps 450 below Kurseong and of a little more than 600 below Birond, the theoretical amount of deflection due to the topography would correspond with the observed value at each of these stations. If therefore we could obtain observations at a large number of stations throughout the Himalaya, it might be possible to construct an ideal surface of compensation underlying the mountain system. One naturally hesitates to postulate

[1] S. G. Burrard: The Intensity and Direction of the Force of Gravity in India, *Phil. Trans., Royal Society*, vol. 205 A (1906, p. 298).

the real existence of such a complicated surface at depths ranging between, say 100 and 350 miles below the surface of the Himalaya, and it is more reasonable to assume, as Hayford has done for the United States, that there is under the Himalaya a surface of compensation, but one which lies at approximately the same depth throughout. A further examination of the table shows that the most probable depth for this surface is about 329·8 km., the average residual being on that assumption only—0″·19.[1]

Another feature which is brought out by this table is the apparent difference in the respective conditions at opposite ends of the Himalaya; the deflection in fact gradually increases with the increase in longitude. It would be idle to speculate on the cause of this apparent increase; the number of observations is too small to warrant any serious attempt to draw inferences; furthermore, the existence of a negative meridional deflection merely indicates that the true deflection has a northerly component, but leaves us still ignorant of the real direction of that deflection or of its amount; and until it has been possible to treat the deflection in the prime vertical as Major Crosthwait has dealt with that in the meridian—and that for a large number of stations throughout the Himalaya—it would be futile to offer any hypothesis as to the true cause of such deflection. Prime vertical figures are available for Dehra Dun, however, and, if complete isostatic compensation be assumed to occur at a depth of 329·8 km., there remains an unexplained residual deflection of only 1″·37 to the west. Thus with the assumption of complete isostatic compensation at a depth of 329·8 km., anomalies in the deflection at Dehra Dun can be made practically to vanish.

Depth of compensation under the plains.

Turning now from the mountains to the plains skirting their foot and applying the same methods, the results shown in Table 2 are obtained. Although detailed figures for the topographic deflection are available for only a few stations, *viz.*, Siliguri, Jalpaiguri, Pathardi, Nimkar, Kaliana, Isanpur and Ranjitgarh, still the table shows the striking difference between the conditions prevailing at most of the stations on the plains and at those on the

[1] This figure is of course only a rough approximation; greater accuracy would no doubt result from the employment of the more refined methods—including that of least squares—adopted by Hayford; but the data are too few to warrant any attempt to draw conclusions as to an exact depth of compensation. My object is to compare results for other depths with those that Crosthwait found for 113·7 km., and it seemed better therefore to adhere as closely as possible to the methods employed by him.

Himalaya; there are two exceptions, Siliguri and Pathardi; the anomaly in the deflection at the former station would vanish if complete isostatic compensation were assumed to occur at a depth of about 200 km., and at the latter station if compensation occurred at approximately 329·8 km. Both these stations therefore seem to belong to the Himalaya rather than to the plains as regards their isostatic equilibrium. When the results for the remaining stations are examined, they at once bring out the remarkable fact that the smaller the assumed depth of compensation the more are the anomalies of deflection reduced, although in the case of all stations lying at some considerable distance from the Himalaya, those anomalies still remain large.

TABLE 2.—*Deflections in the meridian at stations on the Indo-Gangetic Alluvium.*

Station.		Observed Deflection.	Topographic Deflection.	ASSUMED DEPTH OF COMPENSATION.					
				55·92km.		113·7 km.		329·8 km.	
G. T. S. No.	Name.	A—G	D	D_r	R	D_c	R	D_c	R
		"	"	"	"	"	"	"	"
224	Siliguri .	—18	—84	—5·54	—12·46	—11	— 7	— 27·20	+ 9·20
166	Jalpaiguri	— 1	—77	—3·01	+ 2·01	— 8	+ 7	—21·93	+20·93
	Pathardi .	—14	—64	—1·05	—12·95	— 3	—11	—12·15	— 1·85
72	Nimkar .	+ 5	—44	—0·26	+ 5·26	— 1	+ 6	— 4·71	+ 9·71
41	Kaliana .	— 1	—58	—0·97	— 0·03	— 3	+ 2	—11·23	+10·23
38	Isanpur .	+ 3	—35	—0·41	+ 3·41	— 1	+ 4	— 3·20	+ 6·20
213	Ranjitgarh	+ 2	—44	—1·74	+ 3·74	— 5	+ 7	—9·71	+11·71
143	Chanduria.	+ 9	—63	—0·54	+ 9·54	— 2	+11	— 9·19	+18·19
	Sora .	+11	—44	—0·11	+11·11	—0·43	+11·43	— 2·90	+13·90
124	Amritsar .	+11	—45	—0·42	+11·42	—1·48	+12·48	— 6·46	+17·46
	AVERAGE .	+0·7	..	..	+ 2·11	..	+ 4·39	..	+11·75

Decrease in deflections at the foot of the Himalaya.

In his valuable paper already referred to, Colonel Burrard has discussed the rate of decrease of the northerly deflection along certain lines connecting stations on the Himalaya with others on the Indo-Gangetic alluvium, and finds that the observed rate is higher than it should be, even if all topographic features were uncompensated—that is to say, on the hypothesis of complete rigidity—and a great deal higher than it would be if complete isostatic compensation occurred at a depth of 113·7 km. Table 3 shows the deflections along certain lines including some of those selected by Colonel Burrard. I have not, however, restricted myself to a depth of 113·7 km., but give figures also for 329·8 km. The result is instructive in that it indicates a possibility, not, I think, hitherto considered, that the depth of compensation under the Himalaya may be different from that under the rest of India, for it will be noticed that if these depths be assumed to be 329·8 km. and 113·7 km. respectively, the calculated difference of deflection is in four cases out of five almost exactly the same as the observed difference. It will be seen subsequently that it is impossible to find any single figure for the depth of complete compensation that will satisfy the geodetic requirements throughout the Indian Empire, and that one depth may prevail under the Himalaya on the one side and another under the Plains and the Peninsula on the other.

TABLE 3.—*Differences of deflection between stations in the Himalaya and others on the Indo-Gangetic Alluvium.*

Depth of compensation (kilometres).	Computed deflection.		Difference.	*Observed Difference.*
	Mussoorie.	**Kaliana.**		
	″	″	″	″
329·8	−33·73	−11·23	−22·96	
113·7	−17·4	− 3	−14·4	
329·8	−33·73	..	−30·73	*−30*
113·7	..	− 3		
	Kurseong.	**Siliguri.**		
329·8	−40·94	−27·20	−13·74	
113·7	−22·7	−11	−11·7	
329·8	−40·94	..	−29·94	*−28*
113·7	..	−11		
	Birond.	**Nimkar.**		
329·8	−27·95	− 4·71	−23·24	
113·7	−14·3	− 1	−13·3	
329·8	−27·95	..	−26·95	*−43*
113·7	..	− 1		

TABLE 3.—*Differences of deflection between stations in the Himalaya and others on the Indo-Gangetic Alluvium*—contd.

Depth of compensation (kilometres).	Computed deflection.		Difference.	*Observed Difference.*
	Birond.	**Pathardi.**		
	"	"	"	"
329·8	−27·95	−12·15	−15·80	
113·7	−14·3	− 3	−11·3	
329·8	−27·95	..	} −24·95	
113·7	..	− 3		−24
	Murree.	**Ranjitgarh.**		
320·8	−18·06	− 9·71	− 8·35	
113·7	−10	− 5	− 5	
329·8	−18·06	..	} −13·06	
113·7	..	− 5		−14

Subdivision of India into geodetic regions.

With regard to the stations in the latter region. no attempt has been made to arrange them into special groups other than the broad divisions adopted by Major Crosthwait. In an exhaustive enquiry into the exact conditions of isostatic equilibrium prevailing in India, it is doubtful if there is any justification for collecting stations into groups until each individual station has been examined with regard to its deflections both in the meridian and the prime vertical, and to the extent to which local geological conditions may be capable of throwing any light on apparent anomalies. We have not yet accumulated sufficient data for such an enquiry and Major Crosthwait's grouping has been retained, being convenient in that it brings together stations having observed meridional deflections of similar sign; thus of the thirty-seven comprised in his regions 3, 4 and 5, only one shows a northerly deflection; all the others show southerly deflections of various degrees of intensity and, so far as the meridional component is concerned, might not unreasonably be grouped all together into a single region lying between the Himalaya and the tropic of Cancer, and practically constituting a belt bounded by the Peninsula on the south and the Himalaya on the north. This I refer to as the Central Region (Pl. 4). Various depths of compensation were assumed and the necessary corrections applied to the detailed figures for the topographic deflection at more than half the stations included in Major Crosthwait's regions 3, 4 and 5. In almost every case it was found that the greater the assumed depth of compensation the greater was the discrepancy between the observed and calculated deflections. It would be tedious to quote the long and detailed calculations involved and it will be sufficient to say that the unexplained positive residual always remains large, but the smallest, though still considerable, value for the mean of all the 37 residuals in this belt is obtained when the depth of compensaton is taken as =0, that is to say, when complete compensation is assumed to occur at the surface.

The Peninsular stations have been grouped by Major Crosthwait into three regions, his Nos. 7, 8 and 9, or Western India, Eastern India and Southern India respectively. Although this grouping again is not altogether satisfactory from a geological point of view, especially as regards stations near the common borders of the regions, it will serve the present purpose sufficiently well to be retained. Here again to some extent we find grouping into deflections of similar sign. Of the 23 stations in region No. 7 (Western India), all except three show a northerly meridional component of the deflection: at every station in region No. 8 (Eastern India) the meridional component is also northerly, whereas in region No. 9, the extreme southern part of the Peninsula, it is irregular in direction. A certain number of stations was chosen from each of these regions and the effects of different depths of compensation calculated. The results are summarised in Tables 4-6, which show the respective residuals, $R=(A-G)-D_r$, or anomalies between the deflection as actually observed and as calculated on the assumption of complete isostatic compensation at the various depths.

TABLE 4.—*Anomalies of the meridional deflections in Region No. 7: Western India.*

	Depth of compensation in kilometres.				
	0	113·7	329·8	600	1,000
	"	"	"	"	"
Colaba	−9	−9	−7·75	−5·69	−2·41
Damargida . . .	−1	−1	−0·71	+0·71	+2·51
Harnasa	0	0	+0·68	+1·94	+4·47
Peddapad . . .	−6	−6	−5·15	−4·69	−1·03
Pialmudi	−5	−5	−4·73	−2·34	−0·39
Nitali	−3	−3	−2·70	−1·63	+0·80
Mavinhunda . . .	+1	−1	+0·09	+1·87	+4·70
Thikri	+4	+4	+4·15	+5·33	+4·74
AVERAGE .	*−2·4*	*−2·6*	*−2·01*	**−0·56**	*+1·80*

TABLE 5.—*Anomalies of the meridional deflections in Region No. 8 : Eastern India.*

	Depth of compensation in kilometres.				
	0	113·7	162·2	329·8	600
	″	″	″	″	″
Waltair	−8	−2	+0·30	+5·70	+11·69
Cuttack	−7	−4	−2·71	+1·25	+ 5·89
Pathaidi	0	+1	+1·17	+2·51	+ 4·79
Nialamari	−7	−6	−5·28	−3·50	− 0·78
Darutippa. . . .	−3	−2	−1·82	+0·70	+ 3·87
Vanakonda	−6	−5	−4·29	−2·94	− 0·46
AVERAGE .	*−5·2*	*−3*	*−2·10*	+*0·45*	+ *4·17*

TABLE 6.—*Anomalies of the meridional deflections in Region No. 9 : Southern India.*

	Depth of compensation in kilometres.			
	0	113·7	329·8	600
	″	″	″	″
Kutiparai	+3	+7	+10·89	+14·78
Bangalore	−5	−4	− 3·45	− 1·22
St. Thomas' Mt.	+5	+6	+ 7·76	+10·25
Yettimalai	0	+1	+ 3·62	+ 6·75
Honnavalli	−2	−1	+ 0·05	+ 2·00
Koranur	−6	−7	− 5·13	− 3·11
Bommasandra	+6	+4	+ 8·84	+ 8·31
Gudali	0	0	+ 1·91	+ 4·69
AVERAGE .	+*0·13*	+*0·75*	+*3·06*	+ *5·43*

Depth of compensation under the Peninsula.

The tables indicate somewhat remarkable conditions : namely, complete isostatic compensation at a depth of about 600 kilometres in Western India, at about 329·8 km. in Eastern India and at the surface in Southern India. The prevalence of such conditions in the stable Peninsula is certainly rather improbable. If, however, the results of the three regions be combined we find that the mean residuals are, on the assumption of depths of compensation of 0, 113·7, 329·8 and 600 kilometres respectively, $-2''·23$, $-1''·5$, $+0''·51$ and $+2''·91$. If therefore complete compensation were to occur at 329·8 km. under the Peninsula, the mean discrepancy between the observed and computed deflections in the meridian would be only $+0''·51$. On the other hand individual discrepancies would be considerable and if we include the central belt—Crosthwait's regions 3, 4 and 5—with the Peninsula, the mean deflection for the combined areas rises to over $+7''$. If, lastly, we assume that complete compensation takes place at the surface throughout the whole area to the south of the Himalaya, the mean residual of the meridional deflections at all the stations included in the tables given by Major Crosthwait on pages 10 to 13 of his paper, that is to say in regions 3 to 9, amounts to only $+0''·54$. This is no doubt an improbable solution so far as the Indo-Gangetic alluvium is concerned, but it points to the possibility, already suggested by the figures included in Table 3, that the conditions of isostatic equilibrium may be mutually different in the Himalayan and extra-Himalayan regions respectively.

Since the rejection by the scientific world generally of the theories of the "catastrophists," it has become a recognised axiom that the great geophysical processes are slow and gradual. There is no reason to regard the process of isostatic adjustment as an exception to the general rule, and it would be surprising if the conditions of equilibrium under one of the oldest continental areas in the world should prove to be identical with those prevailing beneath one of the most recently elevated.

Necessity for further investigation.

This is only put forward as a suggestion, for I fully recognise that the calculations from which it is deduced are too incomplete to justify the formulation of any definite hypothesis. They were undertaken merely with a view to ascertaining how far a postulated sub-crustal crack could be said to be the only, or the most probable, phenomenon that would satisfy the geodetic requirements, and, incomplete as they are, they seem to show that the problem of isostatic compensation is a much more complicated one in the case of India than in that of the United States and that it calls for more extensive investigation, on the lines followed by Hayford, before it can be safely used as the basis of a new hypothesis. It seems specially desirable to extend the investigation to as many stations as possible and to include in all cases the deflections in the prime vertical as well as those in the meridian, and to consider the effects of under- and over-compensation not only in the Himalaya but also on the Indo-Gangetic alluvium. Materials for such further investigations are to be found in the valuable observations already published by the Survey of India; to deal with them all as Major Crosthwait has dealt with the meridional deflections in his recent paper will be a long and tedious undertaking, and is not likely to be complete for many years. In the meantime I have made an attempt to show that the hitherto accepted view as to the nature of the depression in which the Indo-Gangetic alluvium lies, while being satisfactory from the geological point of view, has not been clearly proved to be untenable from the geodetic. I have dealt with only a small series of observations, but they were all for which sufficient topographic details were available; time unfortunately would not permit me to attempt to emulate the arduous calculations carried out by Major Crosthwait, and these notes, which are admittedly rough and have been put together in such odd moments as could be found between intervals of more pressing work, are merely the outcome of an attempt to extend the application of already available data for most of which I am indebted to the courtesy of the Superintendent of the Trigonometrical Survey. They do not pretend to embody an accurate investigation of the phenomena of isostatic compensation in India, but are published partly with a view to drawing attention to certain aspects of the problem which do not seem to have received adequate treatment, and partly lest silence on the part of geologists in India should be construed into an admission of the alleged inadequacy of the generally accepted hypothesis as to the origin of the Himalaya and the nature of the Indo-Gangetic depression. It is freely admitted—especially in view of the large anomalies at individual stations—that results based on geodetic data derived from observations made at only six Himalayan stations do not justify the assumption of complete isostatic compensation throughout the range at an approximate depth of 329·8 km., but there is no greater justification for rejecting the hypothesis of the existence of comparatively normal conditions merely because the assumption of isostatic compensation at a depth of 113·7 km., does not satisfy the requirements of the case. I have in fact endeavoured to show that all possibilities have not yet been exhausted of reconciling the observed geodetic anomalies with prevailing hypotheses and that it would be premature to adopt a theory for which there is no geological evidence until all existing theories have failed; for, as Colonel Burrard has justly observed, "an imaginary subterranean cause is not a safe explanation of theoretical anomalies, unless it be accompanied by direct proof from the ground."[1] It is on the ground itself that we must seek the cause of the anomalies and this can be done only by careful analysis of all the geodetic results concurrently with a detailed examination of the geological conditions at each station.

Such an investigation would entail also the re-calculation of some of Major Crosthwait's figures for topographic deflection, for it would be necessary to give due weight to the lower specific gravity of the alluvium which covers such a large part of the central belt. Major Crosthwait has followed Hayford in adopting 2·67 as the average density of the crust, but at stations on, or near the edge of, the alluvium the error involved in calculating the topographical corrections for the smaller rings, between say Nos. 23 (1 mile) and 10 (100 miles), on the assumption that the density of the alluvium is as high as 2·67, is likely to be appreciable.

The intensity of gravity.

In connection with Colonel Lenox Conyngham's investigation of the intensity of gravity at Kew and Greenwich,[2] Dr. Aubrey Strahan made a detailed calculation of the specific gravities of the materials underlying those places and it was found that the average density of the 1,140 feet of post-Palæozoic rock under Kew was 2·06; this comprised almost entirely beds of Cretaceous and Tertiary age, which may be safely assumed to be more compact than the Indo-Gangetic alluvium, and it would be reasonable to take 2 as a maximum for the specific gravity of at least the upper part of the alluvium; the figure will probably rise in the deeper layers, but it can hardly exceed the density of Siwalik sandstone, and 2·2 seems a reasonable figure to adopt for the average specific gravity of the alluvium. The Indo-Gangetic area would therefore have the effect of a depression filled with material the ratio of the density of which to that of the average crust would be $\frac{2\cdot2}{2\cdot67}$ or 0 83. If the depth of the alluvium is great, the effect on the topographic

[1] *Survey of India, Professional Paper* No. 5 (1901), p. 24.
[2] *Survey of India, Professional Paper* No. 10 (1908).

deflections might be considerable. I have not attempted to estimate the effects on the computed deflections, as we have not sufficient data for the determination of the depth of the alluvium. In this connection, however, the subjoined figures for depth have been calculated from the values for the intensity of gravity as determined at various places on the alluvium by Colonel G. P. Lenox Conyngham[1]; no correction has been made for isostasy, the simple Bouguer values for excess or deficiency of gravity $(g''_0 - \gamma_0)$ being employed. My figures are probably too high, therefore, but are not devoid of interest and I give them for what they are worth.

Colonel Lenox Conyngham's results are based on the equation

$$g_0 = \gamma_0 - \gamma_0 \cdot \frac{2h}{R} + \gamma_0 \cdot \frac{3}{2} \cdot \frac{h'}{R} \cdot \frac{\delta}{\Delta} - \gamma_0 \cdot \frac{3}{2} \cdot \frac{h'}{R} \cdot \frac{\delta - \theta}{\Delta} + O.$$

where

g_0 = the theoretical value of the intensity of gravity at any given station;

γ_0 = its value at sea level in the same latitude $= 978\ (1 + 0{\cdot}005310 \sin^2\phi)$, ϕ being the latitude of the station;

h = height of station above sea level;

R = mean radius of the earth = 21 feet $\times 10^6$;

Δ = mean density of the earth $= 5{\cdot}6$;

δ = mean density of the crust $= 2{\cdot}8$;

θ = actual density of superficial rocks at station;

h′ = thickness of layer having density of θ;

O = an orographical correction.

Deficiency of gravity correlated with local deficiencies of density.

In employing this equation at stations in India, Colonel Lenox Conyngham applied all the above corrections except the third; this amounts to the assumption that the surface density is uniform. In most cases the assumption is probably justified, but at stations on the alluvium allowance should be made for the deficiency of density and the correction $\gamma_0 \cdot \frac{3}{2} \cdot \frac{h'}{R} \cdot \frac{\delta - \theta}{\Delta}$ is probably important. In order to apply it, it would be necessary to know the depth of the alluvium. This of course we do not know, but if we asume that the discrepancies between the calculated and the observed values for the intensity of gravity at stations on the

[1] *Survey of India, Professional Paper No. 10 (1908).*

alluvium are due to defective density, we can find the thickness of material of low density that would be required to give rise to the observed discrepancy. For instance, Colonel Lenox Conyngham found the difference between the observed and theoretical values at Jalpaiguri to be —0·096 cm.; that is to say, the observed value was 0·096 dynes less than it ought to be on the assumption that the surface density at Jalpaiguri is 2·8. There is probably a very considerable thickness of light material, composed of gravels, sands and some clays, underlying that station and having an average density of not more than 2·2; the effect of this would be to reduce the intensity of gravity and, if we assume that the whole deficiency of gravity is due to the lightness of the underlying material, then the equation

$$0{\cdot}096 = \gamma_o . \frac{3}{2} . \frac{h'}{R'} . \frac{\delta - \theta}{\Delta}$$

$$= (979{\cdot}035)\ \frac{3}{2} . \frac{h'}{21 \times 10^6} . \frac{2{\cdot}8 - 2{\cdot}2}{5{\cdot}6}$$

will give the value of h′ or the thickness of light material required to produce the necessary discrepancy.[1] The thickness thus calculated for the alluvium under Jalpaiguri would be a little under 13,000 feet.

Depths of alluvium uncorrected for isostatic compensation.

Similar calculations have been made for various other places on the alluvium and at the foot of the Himalaya, and give figures ranging from 3,600 feet to nearly 20,000 feet; *e.g.* :—

			Feet.
Siliguri	(26°42′	: 88°27′)	18,300
Dehra Dun	(30°19′	: 78° 6′)	16,800
Roorkee	(29°52′	: 77°54′)	14,300
Nojli	(29°53′	: 77°40′)	12,700
Kaliana	(29°31′	: 77°39′)	7,500
Kesarbari	(26° 8′	: 88°33′)	6,100
Meerut	(29′ 0′	: 77°42′)	3,600

As already pointed out, the figures on which these calculations are based are the Bouguer values and have not been corrected for isostasy. Major H. McC. Cowie, R.E., of the Survey of India, who has recently done much valuable work in connection with the determination of the anomalies of gravity at a number of stations in

[1] Without correction for isostasy the figures can only be approximate; it has been considered advisable to take the extreme case in which it is assumed that the whole discrepancy is due to deficient density. This naturally makes the depths arrived at maxima.

various parts of India[1], has, however, applied partial corrections for isostasy, on the assumption of complete compensation at a depth of 113·7 km., to the values of $g''_0 - \gamma_0$ as determined for certain stations on the Indo-Gangetic alluvium.[2]

Partially corrected figures for depth.

In consequence of these corrections the values for $g''_0 - \gamma_0$ at Roorkee, Nojli, Kaliana and Meerut have been reduced by amounts varying from 30 to 60 per cent., and the corrected values have become −0·070, −0·059, −0·028 and −0·008 dyne respectively. If we adopt Hayford's figure of ·0030 dyne as approximately equivalent to an excess or deficiency of 100 feet of underlying material[3], the anomalies at the above four stations would correspond to the following approximate deficiencies of material of density 2·67[4] :-

	Feet.
Roorkee	2,333
Nojli	1,967
Kaliana	933
Meerut	267

If these deficiencies be regarded as due to the presence below each station of material having a density of only 2·2, the approximate thicknesses of such material required to produce the apparent discrepancies would be, at :—

	Feet.
Roorkee	13,300
Nojli	11,200
Kaliana	5,300
Meerut	1,500

Although these figures are only approximate, their percentage of error is small and there is no doubt that the exact depths, deduced on the same lines, would still be strictly of the same order of magnitude. Their close correspondence with the figures obtained independently from the Bouguer values is striking.

[1] *Extracts from Narrative Reports of Officers of the Survey of India, 1907-08* (1910), *1908-09* (1911).

[2] S. G. Burrard : *Origin of the Himalaya Mountains*, p. 25.

[3] J. F. Hayford and W. Bowie : *The Effect of Topography and Isostatic Compensation on the Intensity of Gravity* (1912), p. 111.

[4] I have assumed that Major Cowie has employed Hayford's figure for the density ; if, however, he used 2·8—the figure usually employed in India in connection with the Bouguer values,—the effect will be to reduce the depth given for the alluvium in each case by about one-fifth.

The above results indicate that the floor beneath the alluvium has a steady, but quite gentle, slope—a little over 2°—towards the mountain foot. Even under Dehra Dun there is no sign of any great deepening, although the figure for depth given on page 165 is perhaps too low, since the thickness of the post-Siwalik deposits may not be very great; at the same time, the beds below the Dehra gravels are largely composed of Siwalik conglomerates and soft sands, all of low specific gravity, and it is quite possible that wherever the apparent depth is great the lower layers may include Siwaliks. Even if we assume that all the above figures include nothing but alluvium, the effect will merely be to bring their order of magnitude into accord with that of the known thickness of the Siwalik deposits, a not unreasonable figure for accumulations that have been forming continuously since the beginning of the Pleistocene period.

Nature of Indo-Gangetic trough deduced from above figures.

Thus the geodetic evidence seems to confirm the generally accepted view that the Indo-Gangetic depression is a broad basin, shallow on the outer side and sloping gently inwards toward the Himalaya, from which it is separated by a steep wall resulting from the series of reversed faults which separate the older geological systems from the younger.

EXPLANATION OF PLATES.

PLATE 3.—Fig. 1. Photograph of a model prepared by Major M. O'C. Tandy, R.E., of the Kumaun and Garhwal Himalaya. The vertical scale is 8½ times as great as the horizontal.

Fig. 2. View south-eastwards over the ridges of the Lesser Himalaya from the General Post Office, Simla. Only the upper slopes are seen, the deep valley-bottoms being hidden from view.

PLATE 4.—Index map showing the regions and plumb-line stations referred to in Tables 1 to 6.

NOTE ON A TWINNED CRYSTAL OF HAMBERGITE FROM KASHMIR. BY R. C. BURTON, B.SC., F.G.S., *Geological Survey of India.* (With Plate 5.)

THE crystals forming the subject of this note were obtained from a collection of minerals brought from the Kashmir sapphire mines by Mr. C. M. P. Wright. These minerals were obtained from the pits in the granite débris containing the sapphires, and some of them have been recorded from the intrusive granite pegmatite of the valley in which the sapphires are found.[1] They include cookeite, prehnite, green and brown tourmaline, beryl, euclase (not yet definitely determined), and amblygonite besides many interesting twinned crystals of quartz.[2] Hambergite has previously been recorded by Brögger[3] from a pegmatite of alkali syenite in the Langesund Fiord, South Norway, and by Lacroix[4] from two localities in Madagascar, at one of which the mineral was obtained from a pegmatite containing triphane (spodumene), beryl and rubellite. Although the crystals of hambergite from Kashmir were not found *in situ*, it is highly probable, from La Touche's description of the valley, that they are derived from the neighbouring pegmatites, and are thus similar in manner of occurrence to the crystals of hambergite from Norway and Madagascar. My investigation proves the Kashmir mineral to have the same properties as those previously recorded by Brögger and Lacroix. The determinations are as follows:—

Hardness = 7·5, refractive index in sodium light, measured by the method of Schroeder van der Kolk = 1·57. Specific gravity = 2·36.

Composition.	Found by analysis.	Calculated.
H_2O	10·21	9·6
BeO	52·40	53·3
B_2O_3	(37·39)	37·1
	100·00	100·0

[1] T. D. La Touche: *Rec. G. S. I.*, vol. 23, p. 59.
[2] F. R. Mallet: *Rec. G. S. I.*, vol. 32, p. 228.
[3] W. C. Brögger: *Zeitschr. f. Kryst.*, vol. 16, p. 65 (1890).
[4] F. Lacroix: *Bull. Soc. Min. France*, vol. 32, p. 320, and vol. 33, p. 49.

For analysis the mineral was finely powdered and dissolved in hydrofluoric acid on the water bath; the residue was dissolved in water and beryllium hydroxide was precipitated with ammonia. After ignition the precipitate was weighed and fused with sodium carbonate according to the method of Wunder and Wenger [1] for the separation of aluminium and beryllium; by this means aluminium was proved to be absent. The water was calculated as loss on ignition, but the boric acid was not determined owing to lack of material.

Crystallography.—The angles of the crystal were measured by means of a Fuess telescope goniometer, but this method was not altogether satisfactory because the pyramid faces are curved and imperfectly developed and the faces in the brachypinacoid zone are striated and give duplicate images. Subsequently the crystal was remeasured with a Fuess contact goniometer to check the results and the calculations are based on the first series of measurements.

The following forms are present (see Plate 5 and Fig. 1). *a* (100), *b* (010), *c* (001), *m* (110), *p* (221), *x* (?121) and *y* (? 321).

	Measured.	Calculated.
(010)⌃(001)	90°10′ ; 89°50′	90°
(010)⌃(110)	51°17′	51°23′
(010)⌃(0$\bar{1}$0)	180°10′	180°
(110)⌃(010)	102°30′	102°46′
(110)⌃(221)	26°20′	23°14′
(001)⌃(221)	63°10′	66°46′
(221)⌃(221)	75°17′	69°59′

A close examination of the crystal reveals, in addition to the above faces, two pyramids *x* and *y* and a small brachypinacoid face, which is feebly developed. The *x* and *y* faces can only be recognised by the fact that they reflect the light feebly on rotation of the crystal, their development is so elementary that they should merely be represented by a line in the figure; it is impossible to measure their angles accurately; one measurement gave the angle between (221) and *x* as 12°; *x* is thus the pyramid (121) and *y* may possibly be (321). The macropinacoid

[1] *Zeitschr. für. Analyt. Chem.*, 1912, p. 470.

is very feebly developed as a curved striated face on the extreme left of Plate 5. The re-entrant angle between the cleavages

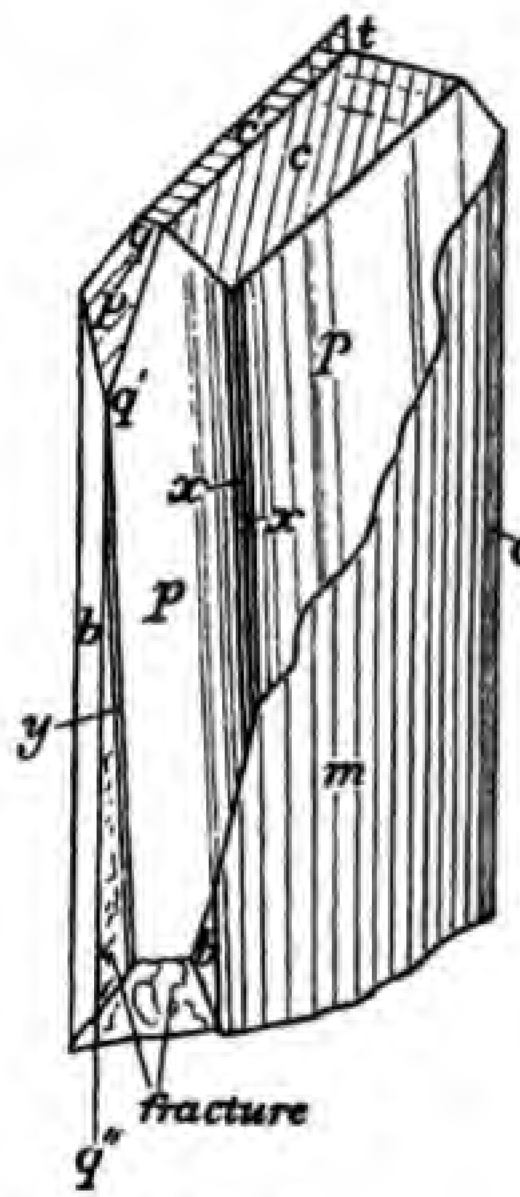


Fig. 1.

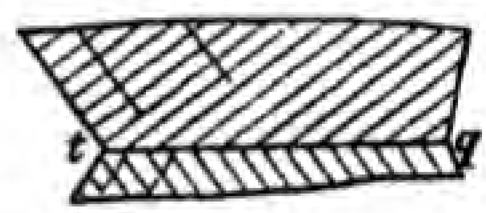


Fig. 2.

on the left-hand side of Plate 5 is seen from the above table of angles to be double the angle between (010) and (110), and proves that the crystal is twinned on the prism (110). The length of the crystal is 1·5 cm. In three cases the agreement between the angles measured and calculated is not good, but is as exact as could be expected considering that the pyramid faces are curved and imperfectly developed. If the basal pinacoid is closely examined, it is found to be striated in five different directions as shown in fig. 2. The line *tq* is parallel to the plane (110) and is thus the trace of the twin plane on (001). The other well developed striæ are at an angle of approximately 39° to the line *tq* and thus represent the traces of the orthopinacoidal cleavage on (001); they are seen to be perpendicular to a more feebly developed set of striæ representing the brachypinacoidal cleavage. The twin can be explained as due to a rotation of half the crystal through 180° on the plane (110); it follows that figure 2 represents the faces (001) and (00$\bar{1}$) in continuation with one another; hambergite is therefore holohedral. All the faces of the crystal are striated to a greater or less extent, the brachypinacoid and the unit prism are striated vertically, the latter very strongly and the former feebly; the striations on the pyramid faces are parallel to the edge between (221) and ($\bar{2}21$). The vertical striations on the brachypinacoid are stated by Lacroix to be etching figures (*figures de corrosion*); Sokolow [1] on the other hand inclines to the belief that they are due to negative crystals, "negative ursprüngliche Einschlüsse, die gelöst wurden". For the purposes of examination the crystal was immersed in water and regarded in transmitted light; it was found to extinguish as nearly as possible parallel to the longitudinal striæ on the brachypinacoid, these longitudinal striæ are distinctly shown, but I failed to observe any pyramidal terminations as detected by Lacroix on the macropinacoid, in fact the striæ seem to be non-terminated. In some cases the striæ on the prism are etched to a considerable depth in the crystal face and end abruptly against a short transverse irregular pit parallel to the basal pinacoid; on the other side of this transverse pit they are continued on a different alignment. It is also noticeable that, where the striæ are poorly developed, their place is taken by a series of small etching figures, whose longer axes are placed vertically. The same phenomena were observed on a crystal of hambergite from Madagascar; it is thus probable that these striæ are etching figures as originally suggested by Lacroix.

From a study of the hambergite from Kashmir we thus record the following facts:—

Striations can be observed on the faces (100), (010), (001), (110) and (221), and the crystal is twinned on the prism (110). The unit prism is much larger and better developed than the pinacoids, although it is uneven, having a stepped or wavy, instead of a straight outline. The pinacoidal cleavages are well shown and the surface of the brachypinacoidal cleavage has a brilliant lustre. The following new faces have been observed:—

(221), (121), (321 (?)). From a consideration of the nature of the twinning hambergite is proved to be holohedral,

[1] "Über eigentümliche Figuren auf Spaltflächen von Hambergit. *Ann. de l'Institut des Mines*, St. Petérsbourg, vol. 2, pt. 5 (1910), p. 394.

the faces (001) and ($00\bar{1}$) being continuous in the same plane.

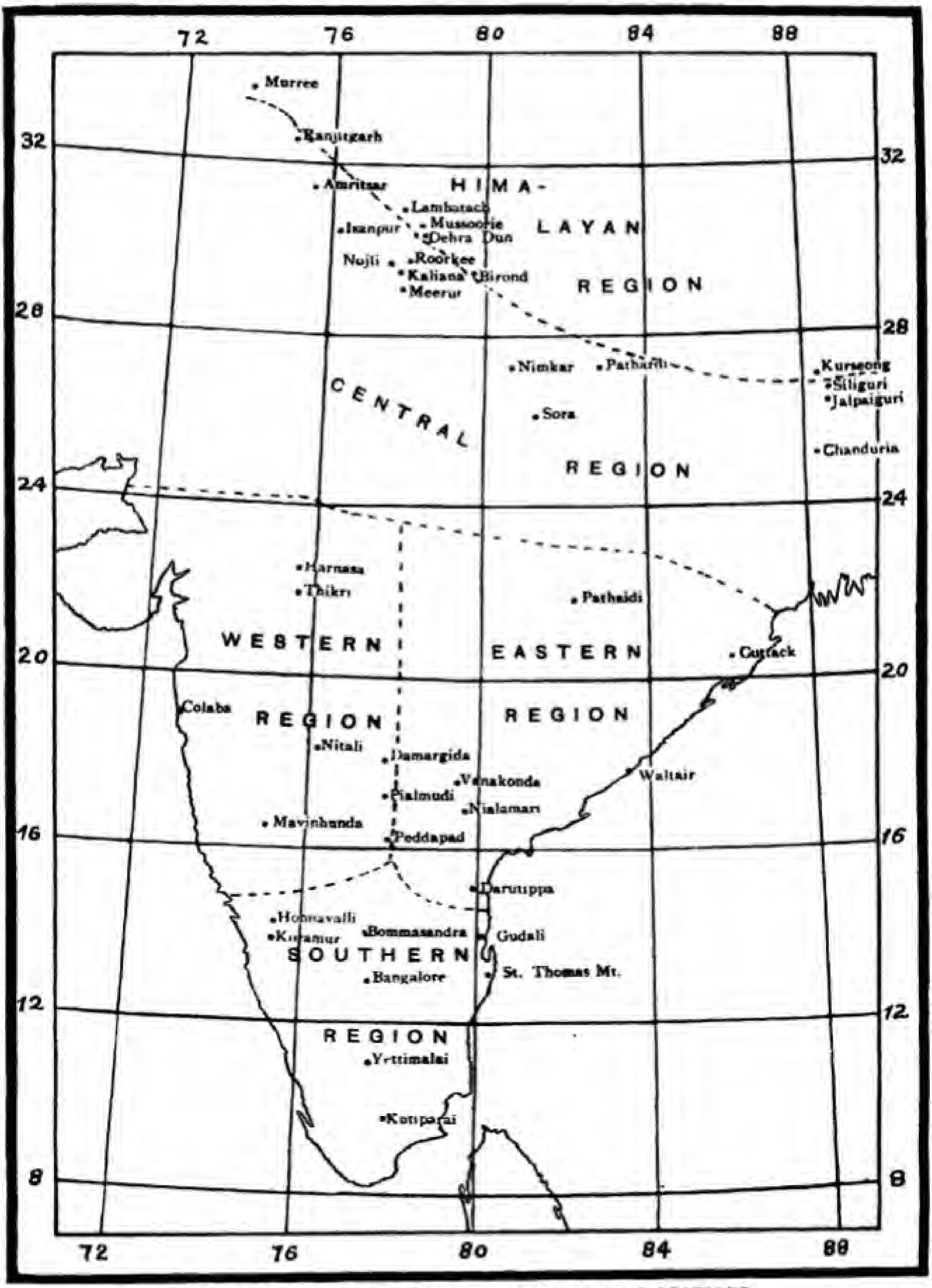
In conclusion I must express my best thanks to my colleagues Messrs. Christie and Fox for their aid during the course of the investigation.

FIG. 1. THE KUMAUN HIMALAYA.

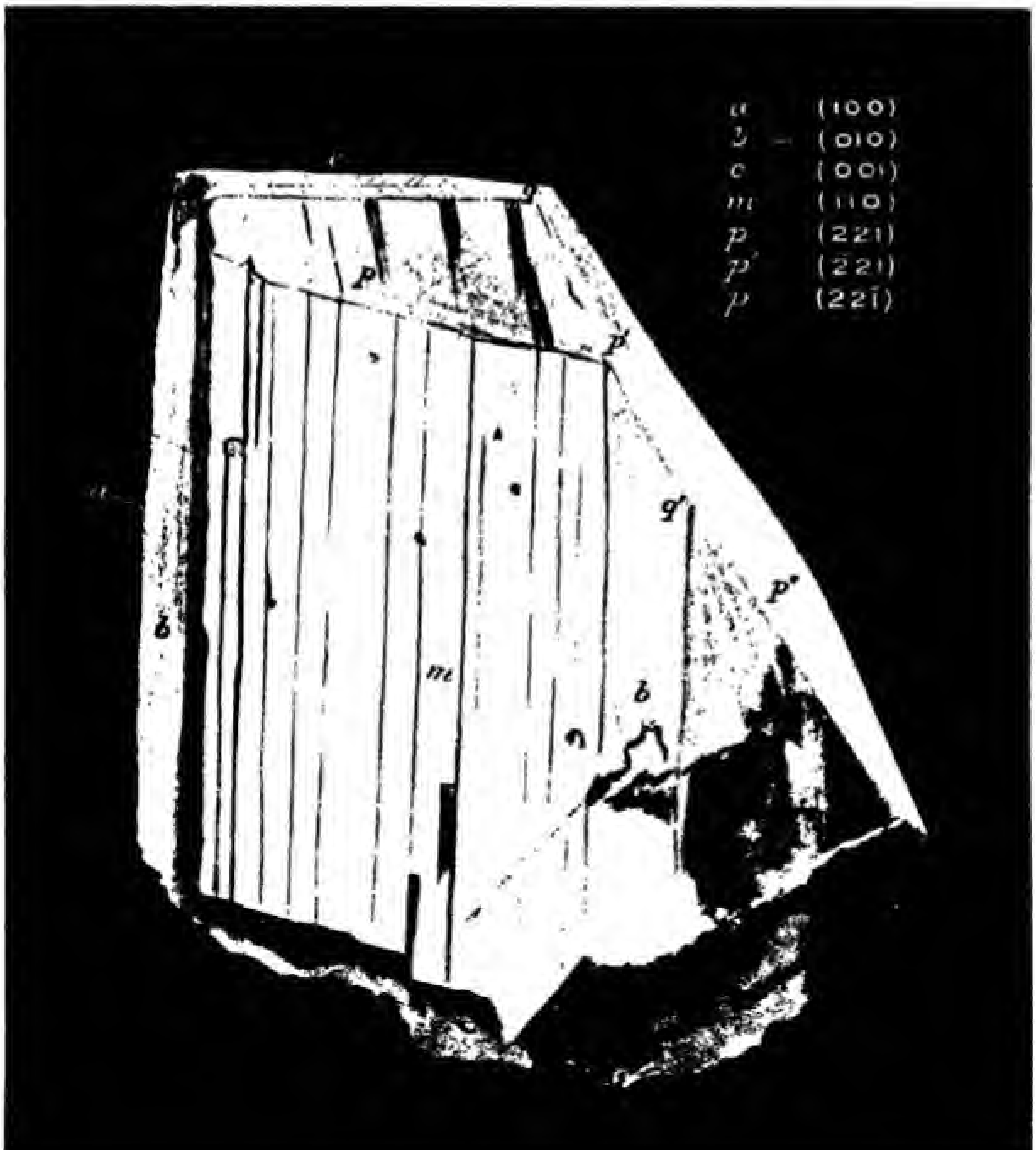
from a model constructed by Major M. O'C. Tanay, R.E.

FIG. 2. THE LESSER HIMALAYA, AS SEEN FROM SIMLA.

looking S. E.



INDEX MAP SHOWING REGIONS AND PLUMB-LINE STATIONS INCLUDED IN TABLES 1–6.



G. S. I. Calcutta.

HAMBERGITE twinned on (110)

(Enlarged seven times.)

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1913. [December

CONTRIBUTIONS TO THE GEOLOGY OF THE PROVINCE OF YÜNNAN IN WESTERN CHINA. (I) THE BHAMO—TÊNG-YÜEH AREA. BY J. COGGIN BROWN, M.SC., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 6 to 17.)

CONTENTS.

INTRODUCTION.

THE greater part of the country to be described in this paper lies in the valley of the Taping, a tributary of the Irrawaddy which enters that river immediately to the north of Bhamo in Upper Burma. A small proportion of the area is in Burma, but the majority lies across the frontier in the Chinese Province of Yünnan, where it forms part of the Têng-yüeh district in the prefecture of Yung-ch'ang Fu, and of the semi-independent Chinese Shan States of Kan-ngai (Möng-na), Nan-tien (Möng-ti), Ho-hsa, La-hsa (Möng-hsa) and Möng-wan.

The two towns Bhamo (Lat. 24° 15′ : Long. 97° 16′) and Têng-yüeh (Lat. 25° 2′ : Long. 98° 33′) lie on the route which has served as the main artery of trade between Burma and Western China for centuries.

Leaving Bhamo which is situated on the flat plain of the Irrawaddy alluvium at a height of 360 feet above the sea, the road proceeds in a north-easterly direction and soon enters the hills through which the Taping has cut its narrow and gorge-like valley. Owing to the dense vegetation and the great depth to which decomposition has taken place very few rock exposures are visible in these ranges, but sufficient evidence has been collected to show that they are formed almost if not entirely of crystalline rocks.

After crossing the Chinese frontier, the road descends slightly into the Chinese Shan State of Kan-ngai and for some days' journey goes over the level lacustrine deposits of the Taping valley. A greater contrast could not be imagined than that presented by the steep slopes of the practically uninhabited frontier hills, clothed in thick evergreen forests, and the broad Shan valleys forming open park-like country, bounded by grassy slopes, covered everywhere with fertile rice lands and supporting the dwellers of many a prosperous village. The Kan-ngai plain runs from south-west to north-east, is from 35 to 40 miles long and from 2 to 4 miles broad. It is bounded by gneissic ranges which rise to heights of 7,000 and 8,000 feet above the sea and separate it from the States of Ho-hsa and La-hsa, called Möng-hsa by the Shans and Maingtha by the Burmese. These latter States are in their turn separated from the next one to the south, (Möng-wan) by a high gneissic dividing range.

The Kan-ngai State at its north-eastern extremity ends in a ridge which runs up close to the river from the south and has forced it into a narrow defile known as the Hu-lu-ko gorge, through which the Nam-ti flows after the Taping has split off and turned to the north (Pl. 15). Across this ridge lies the State of Nan-tien. The route still proceeds in the same general direction crossing gneisses and mica schists with granitic intrusions, high above the steep sides of the valley, which must be scenes of frequent and by no means insignificant landslips, judging from the state of the slopes and by the immense amount of rock detritus brought down into the open plain below.

The Nan-tien plain, which has a general elevation of about 3,600 feet, is not so extensive as that of Kan-ngai, extending only for about 15 miles down the left bank of the Nam-ti (Pl. 15). The paddy land is seldom more than one mile broad though the plain is thickly populated by both Shans and Chinese. Owing to the large amount of sandy and rocky detritus brought down by the side streams into the main valley, some of these tributaries now have the curious appearance of running above the general level of the plain itself. Both plains are bounded by terraces of fluviatile and lacustrine deposits of late Tertiary age which often attain a great thickness, and beyond which rise the gently rounded and much denuded slopes of the crystalline rocks.

Soon after leaving Nan-tien, the capital of the State, the road swings round to the north, and from an elevation of 3,700 feet ascends at once a further 1,500 feet to the small plateau of Ho-shuen-shan, which is composed of rocks of the Têng-yüeh Volcanic series, the southern edge of which is only some 10 miles from Têng-yüeh itself. At the commencement of the ascent near Jê-shui-tang hot water flows from the hillside in a number of springs, which have deposited large quantities of travertine. Beyond the village of Hsiao-hoti-ho the lava fields of the volcano She-toe-shan are first met with, the whole of the surrounding country being covered with masses of broken and tumbled flows of heavy, black, slaggy appearance, as often as not full of steam holes and exactly resembling recent pumice. Over these beds there is only the scantiest growth of ferns and bracken and no soil to speak of.

The town of Têng-yüeh, which is called Momien by the Burmese and by previous writers, is situated at a height of 5,500 feet above sea level, in a plain some 6 miles long by 3½ miles wide (Pl. 16). It is bounded on all sides by high grassy hills, which rise up very steeply on the east to a height of over 7,500 feet, but on the other sides and especially on the north slope up more gradually. Some of the lower slopes are under dry rice cultivation. The plain, which is intensely cultivated, is watered by a small stream, the Sin-ch'ia Ho, which enters by the north-east and flowing along the northern side after approaching close to the walls of the town, empties itself 150 feet over an imposing waterfall into the lower plain of Ho-shuen-shan (Pl. 13). The Têng-yüeh plain owes its origin to lacustrine and fluviatile deposits of late Tertiary age, while the peculiar topography of the surrounding hills is brought about by the rocks of the Têng-yüeh Volcanic series. To the north rise the symeterical slopes of the volcano Tay-in-shan, while to the east—on the other side of the Shweli river, towers the mountain wall of the Irrawaddy-Salween divide, one of the most striking features of the present orography of this part of the world. The Têng-yüeh plain is very thickly populated, the villages, which are often of great size, being usually situated at the edge of the cultivated ground, or on the lower slopes of the hills.

The Ho-shuen-shan valley, which is some 3 miles long by 1 mile broad, is situated immediately below the waterfall and some 400 or 500 feet below the level of the Têng-yüeh plain. The volcano She-toe-shan rises from its centre, and the black, rocky slopes formed by the lavas stand out in marked contrast to the rounded grassy outlines of the granitic and gneissose rocks, which bound the valley to the west (Pl. 7). A small stream from the north meets the Sin-ch'ia Ho towards the southern end of the plain after flowing round the western edge of the volcano.

The geological data which form the basis of this paper were gathered together during the years 1907-1910, when in the course of other duties I traversed the country between Bhamo and Têng-yüeh several times, visited the states of Ho-hsa, La-hsa and Möng-wan, and made various excursions around Têng-yüeh itself. Pressure of other work, especially in the field, has delayed the preparation of the present paper, which it is proposed to supplement in the near future with others describing the geological structure of more distant parts of Yünnan and other regions. The unusual manner of treatment adopted herein demands the explanation that the geological notes were made under difficult conditions, and for the greater part during rapid route marches, when very little time could be spared for minute examination or detailed description. It is hoped that the broad outlines which are given may prove a foundation for the future worker, and go some small way towards the elucidation of the geological structure of this most interesting region.

My colleague Mr. R. C. Burton has undertaken the petrological examination of the rocks of the Têng-yüeh Volcanic series and his report is published in the present number of these Records. I would here express my thanks for his interest and help in the matter.

Previous Observers.

C. L. Griesbach.

This paper[1] deals with country to the north of Bhamo, which was rapidly traversed by both C. L. Griesbach and F. Noetling, but it is near enough to the area under description to merit mention here. It is stated that the entire district north of Bhamo appears to be formed by a succession of flexures of older rocks, all striking more or less north and south and north-east to south-west, which flexures have been extensively eroded by the drainage of the Upper Irrawaddy. By far the greater part of the ground explored was found to be formed of crystalline rocks, amongst which a coarse, porphyritic gneiss is very characteristic in the eastern part reported on. Besides the gneissic rocks, there are also schistose, phyllitic and hornblendic varieties, but the whole group has evidently undergone most extensive folding and crumpling with subsequent erosion, and is now so greatly obscured by sub-recent deposits and vast forests, that, in the writer's opinion, it will for a long time to come be next to impossible to arrive at any clear knowledge of the sequence of the series. It is further considered that certain less crystalline rocks, chiefly limestones which occur in the midst of the metamorphic flexures and seemingly conformable to the latter, belong really to the palaeozoic groups, though actual proofs are wanting. Mention is also made of the widespread alluvial deposits, both fluviatile and lacustrine, which occupy the wide troughs of the Irrawaddy and its minor confluents.

J. Anderson.

This author was medical and scientific officer to the expedition under Colonel Edward B. Sladen which proceeded through independent Burma to Têng-yüeh in 1868, and later, in 1875, he joined that of Colonel Horace

[1] "Geological sketch of the country north of Bhamo." *Records, Geol. Surv., Ind.*, Vol. XXV, Pt. 3, pp. 127-130, 1892.

Browne which had to retire from the frontier.[1] Anderson has given general accounts of the physical features, geology, etc., of the districts which he visited and observes that the frontier hills appear to be largely composed of metamorphic and crystalline rocks, a common variety being a dark bluish-grey, fine-grained gneiss containing layers of felspar. The varieties of structure are said to be numerous, and beds of the very finest grain were found lying alongside others resembling porphyry, while schistose, felspathic and granitoid forms of gniess also occur. The physical geography of the Kan-ngai, Nan-tien and Möng-hsa valleys is outlined, and their superficial deposits are described as consisting of yellowish and bluish clays and sandy loam, with inter-bedded river gravels. To Anderson belongs the discovery of the extinct volcano She-toe-shan (erroneously termed Hawshuenshan), which lies in the little valley of Ho-shuen-shan, a few miles below Têng-yüeh. The Têng-yüeh valley is also described and reference made to the sands and clays of lacustrine origin which fill it.

Ludwig von Loczy.

Loczy was the geologist attached to Count Szechenyi's expedition across China (1877-1880), and made a rapid traverse through Yünnan in 1879.[2] Entering the province to the south-east of A-tun-tzu, he marched down the valley of the Yang-tze-ch'iang to Li-kiang Fu, and thence, still proceeding southwards, to Ta-li Fu. From this city the main westerly route to Bhamo was followed. In the geological section of the report, brief notes, the result of hurried wayside observations, are given, which include a short description of She-toe-shan, some account of the late Tertiary deposits of the Taping plains and a few remarks on the gneisses of the frontier ranges.

Recent changes in the course of the Irrawaddy near Bhamo.

Bhamo is situated on the left bank of the Irrawaddy in Lat. 24° 15': Long. 97° 16', about a mile below where it is joined by the Taping (Pl. 16). In a direct line from east to west the valley is here some 16 miles across and filled with alluvial deposits. An examination of the topography of the district reveals some interesting features, for 6 or 7 miles to the north of the town the river

[1] "A report on the expedition to Western Yünnan *viâ* Bhamo." Calcutta, 1871. "Mandalay to Momien " a narrative of the two expeditions to Western China of 1868 and 1875." London, 1876.

[2] "Die Wissenschaftlichen Ergebnisse der Reise des Grafen Bela Szechenyi in Ost-Asien." Vienna, 1892.

enters its third defile. A mile wide in the plain, quietly flowing between low, sandy banks, the course of the river in the defile itself is no more than 150 yards wide for 30 miles, and in places narrows down to 50 yards. High cliffs rise from both sides of the channel, which is rock-bound throughout the whole of its length. 10 to 12 miles east of the present channel of the river and approximately parallel with it, is a broad open plain at the southern end of which Bhamo is situated, and which at present contains no stream of any importance. The questions which present themselves are, did the Irrawaddy ever flow along this plain, and if so, what has caused it to leave so easy a path and break through mountains 2,500 to 3,000 feet high, composed of metamorphic schists? The answers have been partially supplied by J. M. Maclaren, who has shown that at no very distant time the Irrawaddy flowed beneath the frontier hills, while a tributary stretched from near Bhamo northwards into the hills for a distance of about 30 miles. Beyond its head again another stream flowed northwards to join the Irrawaddy near Sinbo. As both streams sculptured out the country towards their sources, the col which separated them was lowered until the Irrawaddy waters at high flood burst over it, "and hampered by the lack of grade due to its meanderings on its old flood-plain, gladly seized and deepened its new channel. It became, indeed, locally rejuvenated."[1] (Pl. 17.)

The second defile of the Irrawaddy was probably produced in a similar fashion though the evidence is not so clear. The course of the old river bed is now occupied by the Thittaung Chaung and the waters of the parent river may have been tapped by a small tributary near Sinkan. To carry Maclaren's arguments a little further, it seems almost certain that the eroding action of the smaller streams, which are really responsible for these cases of piracy, has been helped by those differential earth movements which we know to have affected this region within very recent geological times. Such recent cases of change are of course not confined to the Irrawaddy, for La Touche has shown that the Nam Tu or Myitnge, the tributary of the former river which drains a large part of the Northern Shan States and joins the parent stream a few miles to the south of Mandalay, has undergone an almost identical change. In

[1] "The course of the Upper Irrawaddy." *Geographical Journal*, Vol. XXX, pp. 507-511.

both cases the bed of the stream has been shifted into higher country to the west of its former line of flow, circumstances which it is difficult to explain as accidental, and which are probably related to the earth movements which have taken place.

The remarkable and rapid changes of level which affect the Irrawaddy near Bhamo are to some extent due to the narrow opening into the northern end of the third defile. As a general rule the whole of the plain along the banks of the main stream and its tributaries the Mole, Taping, Sinkan and Kauk-kwe, is at certain times of the year in a water-logged condition. But with a rise of over 30 feet in the water level at Bhamo to over 80 or 100 feet above the low water mark at Sinbo, near the head of the third defile, this is easily explained, for the parent stream dams back its tributaries by overflowing its banks. Maclaren states that it is related at Sinbo that the river has been known to rise 80 feet in a single night, and that in the great floods of the rains the turmoil of the waters in the basin above the gorge is indescribable. There must therefore be a considerable "banking up" of flood water at the heads of the Irrawaddy defiles, the reflex action of which will tend to push back the smaller streams and so prevent free flow.

Physical Geography.

The undulating though almost level country in which Bhamo is situated, is replaced 10 or 12 miles to the east by ranges of mountains which rise like an unbroken wall to heights of over 7,000 feet, and which run in an approximately north-east, south-west direction. Orographically the outermost range is regarded as the western rim of the Shan plateau, spurs from which contain the second defile of the Irrawaddy between Bhamo and Shwegu. The outermost range contains the peaks Alaw Pum 5,783 and Hkawan Pum 4,748 feet above the sea: near Bhamo it has the small Mole Chaung flowing roughly parallel to it, while the Taping itself breaks across 20 miles to the north-east of the town. Starting in Maru Pum 5,513 feet, and running more or less north and south through the area under discussion, is a second and higher range which south of the Taping forms the actual Burma-China frontier. Long spurs jutting out from this range in a general north-easterly direction determine the courses of the streams which have formed the valleys of Möng-wan, Ho-hsa, La-hsa, and Kan-ngai. The actual frontier line leaves this range where it crosses the Taping, and after proceeding along the latter river, continues up the valley of its tributary the Nampaung Hka, while the hills themselves run north and then north-east through the peaks Prawman Pum 6,440, Pumling Pum 6,920, Malai Pum 8,572 and Talang Pum 8,571 feet, so forming that high and well-defined ridge, which closes the main Taping valley and defines the limits of the Kan-ngai and San-ta States. Further into Yünnan the minor spurs break up into a complicated maze of smaller hills, but the general trend of the higher ranges is north and south, corresponding to the strike of those great systems which further east and north separate the waters of the branches of the Upper Irrawaddy, Salween, Mekong and Yang-tze-ch'iang.

Têng-yüeh and Ho-shuen-shan are in small valleys formed by the headwaters of the Nam-ti, which like those of the Taping have a north and south trend. A high ridge to the east separates the Têng-yüeh plain from the deep valley of the Shweli, which after flowing north and south turns to the south-west in the same way as the Taping does. As a portion of the country herein described lies within the Shweli valley, it may be well to give some account of the upper reaches of the river. The Lung-chiang or Shweli, (as it is known to the Burmese), divides into two streams near Chü-ch'ih, 17 miles north-east of Têng-yüeh. The main stream proceeds in a north-north-easterly direction, but the other branch takes a more westerly course as far as Ku-tung-kai, 22 miles north of Têng-yüeh. Here it divides into two streams, the No-lo Ho, which continues in a north-north-easterly direction almost parallel to the main river and forms the Ming-kuan valley, and the Hsiao-pa Ho which flows from the north-north-west and forms the valley known as T'ien-t'aung-kuan. Another smaller branch of the latter stream forms the Hsi-lien valley. These valleys are separated by single ranges which rise to altitudes of 8,000 to 10,000 feet above the sea, though they are only 8 to 10 miles apart as the crow flies. The mountains which border T'ien-t'aung-kuan on the east, meet at the head of the valley with the western border range in the peak Chien-shan, which is over 11,000 feet above sea-level and is on the frontier itself. Throughout the whole of the Têng-yüeh district, the landscape to the east is dominated by the Kao-liang-shan, the lofty jagged line of peaks which rise to over 15,000 feet further north and separate the drainage areas of the Irrawaddy and Salween.

Classification of strata.

The following rock groups have been recognised in the Bhamo—Têng-yüeh area—

(1) The gneisses, mica schists and crystalline limestones of the frontier hills.
(2) The intrusive granites of the Upper Taping valley.
(3) The metamorphic rocks of the Kao-liang series.
(4) The eruptive volcanic rocks of the Têng-yüeh area.
(5) The later Tertiary deposits of the Taping, Möng-hsa, Möng-wan and Têng-yüeh valleys.
(6) Recent deposits.

The Crystalline series between Bhamo and the Chinese frontier at Ku-li-kha.

The undulating alluvial plain which stretches east from Bhamo is covered with open forest and small trees and bush jungle are not common, though there are many clearings. The plain is dissected by small watercourses in which sections of the sandy beds forming the greater part of the alluvial deposits are sometimes visible. The road runs in a north-easterly direction following the general course of the Taping which is here a placid, slow-flowing stream. After passing the Shan village of Mo-mouk the ascent into the hills commences, but it is not until the 12th mile from Bhamo that the first exposure of the gneiss, which with its associated rocks forms the whole of the Kachin frontier hills, is met with. Very few exposures are indeed visible in this part of the route, and it is only where small streams have excavated through the overburden of decaying vegetable matter and soil that the strata can be studied *in situ*. The gneiss itself is generally of a white colour, with an unusually large amount of quartz and a little biotite mica ; in typical specimens it is coarse-grained. The strike of the foliation planes is north-east, south-west, though often this structure is not well marked and the rock assumes the characters of a gneissose granite.

As soon as the Taping enters the hills it becomes a swiftly flowing mountain stream, full of rapids and cataracts and constricted in a narrow gorge. The road, which is marked out by milestones to which frequent reference is made below, proceeds along its left bank, sometimes close to the river, at other times high above it but seldom out of hearing of the deafening roar of its waters.

Between miles 17 and 21 the track is covered with broken pieces of decomposed gneiss, but owing to the thick soil cap, few exposures are available. At mile 18½ however, a large stream from the south flows down to join the Taping along the strike of the gneiss, which is here north-east, south-west with a dip of 50° to the south-east. The rock is of a greyish white colour and a rather coarse texture, with irregular patches of quartz, much clouded felspar, and many very small biotite laths, but it also has thin well marked and continuous bands of a darker tint, which on microscopical examination have proved to be fine-grained hornblende-mica schists containing a little sphene.

Between Ka-li-chet, (mile 21, elevation 800 feet) and Möng-hkong-hka, (mile 43, elevation 1,250 feet), exposures are commoner, but of much the same type of rock. Up to mile 27 there are practically no outcrops, but between this and mile 32 light and dark coloured gneisses alternate. This dark gneiss contains large porphyritic felspars in a glistening background of quartz, mica and small felspars. Poor exposures of an even-grained gneiss containing quartz veins in places, crop out between miles 32 and 33, and towards 34 schistose bands begin to put in an appearance. On the steep ascent between miles 34 and 35, crystalline limestones of coarse saccharoidal texture are interbedded with the dark variety of the gneiss, which here contains very prominent felspars, but exposures are very small and infrequent.

At the top of the ascent the last view of the debouchure of the Taping on to the Burmese plains is obtained with a far distant glimpse of the Irrawaddy itself. Outcrops are poor from mile 35 to 40, but are sufficient to prove that a light-greyish, compact gneiss is the prevailing type, while towards mile 41 crystalline limestones are seen again. The latter attain a stronger development towards mile 43, where they are pure white in colour, finely crystalline when broken, but weathered into large, discoloured, jagged masses which crop out high above the roadway. The rock with which they are associated hereabouts is a coarse, light coloured gneiss with porphyritic felspar crystals, often an inch in length. At mile 41½ this gneiss is vertical and strikes east-north-east, west-south-west. The frontier is at Ku-li-kha, (elevation 2,000 feet), near mile 51, and for the intervening 10 miles there is no change in the rock exposures with the exception of the occurrence of fine-grained, dark-grey biotite schists which strike east-north-east, west-south-west between miles 44 and 45. The crystalline limestones become coarser and more banded and often take on bluish-grey and pink tints. The gneiss is of the finer, light coloured variety, sometimes rather laminated and pinkish in colour, but near the village of Pa-ch'iao-chai boulders of a coarse white gneiss and of a dark biotite schist were seen.

Crystalline rocks between the frontier at Ku-li-kha and Möngwan.

A traverse was made from Möng-wan in the Nam-wan valley due north into the Ho-hsa, La-hsa valley, and thence across into the basin of the Taping to Man-hsien and Ku-li-kha. As the following route notes show, gneisses, schists and intrusive granite were the only rocks met with.

Möng-wan (Lat. 24°, Long. 97° 59′, Height 3,100 feet), is a Chinese Shan State on the Nam-wan, a tributary of the right bank of the Shweli. The plain itself is about 20 miles long and from 2 to 9 miles broad. After crossing it in a northerly direction, the track begins the ascent of the high range which divides the State from the Ho-hsa, La-hsa valley. Exposures are very rare owing to the ease with which the rocks weather down and to the thick grass growths which hide all traces of their remains. When an elevation of 3,750 feet has been attained, a small stream is crossed, the bed of which is full of big boulders of a reddish-white granite containing large porphyritic crystals of felspar. The track is covered with small pieces of quartz weathered out of this rock. In the cup-like depression formed by a small stream at an elevation of 5,050 feet, large boulders of a rather coarse-grained biotite granite were found, together with a few doubtful exposures of the same rock.[5] From the pass which is reached at 6,050 feet, an excellent view of the Ho-hsa La-hsa plain with the Nam-hsa winding through it was obtained. The valley is not so extensive as Möng-wan, but the ranges on the farther side are far more weathered and are broken up into innumerable smaller valleys. On the descent to the plain, granites of a similar kind to those found on the way up were followed by outcrops of decomposed white gneiss, slabs of which are used to pave the narrow roads connecting the villages.

The road joining the two towns of Ho-hsa and La-hsa runs entirely over the alluvial deposits of the valley, or across the slightly higher ground adjoining them. From an elevation of 4,900 feet at La-hsa the track ascends to the top of the range which divides it from the plains of the Taping. This is reached at 6,150 feet after crossing a belt of low-lying, much weathered, grassy hillocks with very little jungle, and afterwards, the steep slopes composed of a gneissose granite and covered with heavy forest. Looking towards the south-west from this elevation, that is to say in the direction of the British frontier post near Wa-ra Pum, the La-hsa plain with its southern bounding spur joining the parent range in Pum-sen Pum (6,831 feet) is clearly visible. The wide basin of the Taping forming the Kan-ngai State comes in on the other side, and the gap in the hills where the river breaks through them is exceedingly well marked. The frontier ranges themselves appear as a maze of hills north and south as far as the eye can reach, usually in the form of dome-shaped masses, occasionally as sharper peaks, but invariably clothed with dense forest to their very summits. Poor exposures of gneissose granite continue to be found as the descent is made, until 2 miles above Man-shien, where the true crystalline series was again met with, consisting of white, fine-grained gneisses and crystalline limestones, which form well marked bands easily traced along the hillside near Man-hsein. From this village, which has an elevation of 3,200 feet, the Taping valley narrows in, and the road enters the hills again to reach Ku-li-kha. Contorted, fine-grained, bluish-grey gneisses are found 2 miles from Man-hsien, striking north 25° west and dipping towards the east at 38°. Further on massive biotite gneisses occur and near the Chinese outpost at Manhsan Ho, quartz schists strike north-east, south-west and dip south-east at 64°. Crystalline limestone with rarer white gneiss and quartz schists are the only rocks found from this point to the Chinese frontier guard at Ku-li-kha, which has an elevation of 2,580 feet.

The Crystalline series between Nan-tien and Möng-wan.

Nan-tien lies on the main Bhamo—Têng-yüeh route and is separated from Kan-ngai by a small range through which the Nam-ti, the eastern branch of the Taping, has cut a deep and narrow gorge, known as the Hu-lu-ko (Pl. 15). The road to Möng-wan goes through this and then ascends the range itself, and drops into the Möng-hum or Lo-po-ssu-ch'uan valley; proceeding along this it crosses the Nam-hum, Nam-wan watershed and so reaches the Möng-wan plain.

The foot hills of the Nan-tien plain come close to the river at Hsin-chai, where the stream is in a narrow gorge crossed by a bridge. All the streams at this end of the valley contain boulders of gneiss and granite, the prevailing tints of which are light. In the actual gorge itself, which in places is impassable in the rains owing to the sudden rises of the stream, fine-grained gneisses containing small veins of intrusive granite crop out. On the ascent to the top of the dividing range on the south, practically no exposures were found, though near Lihsaw-chai white gneisses were discovered. During the descent to the Möng-hum plain, which is about 13 miles long, both gneisses and gneissose granites were observed. In the bed of the Nam-hum boulders of gneiss, mica schist and very rarely of granite were seen. The road down the valley keeps entirely to alluvial and lacustrine deposits, but from the water worn fragments of rock in the side streams, which always consist of crystalline rocks and nothing else, it is believed that the bounding ranges themselves are made up of such strata.

Near the point where the Nam-hum turns south to join the Shweli, and where the road commences to ascend the high divide, fine-grained, white gneiss outcrops and in a stream a little further on, biotite schists and gneisses were discovered. The road winds a great deal as it ascends the divide, and at 5,000 feet crosses worn and decomposed gneissose rocks. Pebbles of biotite schist, quartz schist and a hornblende schist were obtained from the bed of a small torrent a little above this point. As the elevation increases the jungle becomes thicker, and rock exposures are only found now on the patches cleared for cultivation by the Kachin inhabitants of the hills. The top of the range is reached at 7 miles, elevation 6,200 feet, and here the traveller is rewarded by magnificent views of the beautiful Möng-hum, Möng-wan and Hsiao-lung-ch'uan valleys. Near the top, the hill-side is scattered over with weathered pieces of banded quartz schists and fine-grained mica schists. There is a long, easy descent to the Möng-wan valley over grass covered slopes, but unfortunately there are no exposures to be seen, though small pieces of mica schist strew the path in places. There can be no doubt that the alluvium of the Möngwan plain is underlain by crystalline rocks, for in places about its edges large rounded masses project from the soil. The road across the paddy land is paved with gneissic and schistose rocks, and similar material is brought down by streams from the south side.

The Crystalline series around Têng-yüeh.

Crystalline rocks such as gneisses of various kinds and true mica schists, often with associated granites, continue to form the whole country up to and including the greater part of the Salween-Irrawaddy divide. From the neighbourhood of Nan-tien as far as the Shweli, and for some distance to the north and south of Têng-yüeh, they are largely buried under later deposits, either the late Tertiary silts and sands, or the out-pourings of the volcanic vents which are of such frequent occurrence. Yet there are numerous uncovered patches where the old crystalline foundation rises to the surface, either standing out as islands from the commencement of the changes which recent geological events have brought about, or from which the results of these same events have been removed, by the everyday action of the long continued though slow processes of ordinary denudation.

On the map which accompanies this report it has been found impossible to separate those areas composed of granite from others in which gneiss and mica schist occur. This is partly due to want of sufficient observations as only a very limited amount of time could be given to the survey of boundaries, and partly to the small scale of the only available topographical map. In the immediate neighbourhood of Têng-yüeh true granites are of more frequent occurrence than gneisses or schists.

Anderson has already shown that the ranges bounding Kan-ngai and Nan-tien on the north are composed of crystalline rocks, an observation which I was able to confirm. The largest exposure of granite near Têng-yüeh is to be found in the Pao-fung-tzu ridge to the north-west of the city.

The range which separates the drainage of the Ta-ho from that of the Ku-yung Ho is also composed of the same rock, which is often sculptured into deep jungle-covered ravines. The head waters of the Ta Ho near Chien-ma-chin contain great boulders of a coarse-grained granite. Marching along the Ku-yung-kai valley by the route which eventually reaches Myitkyina in Burma, there are few opportunities for observing the rocks building up the hillsides which close it in, owing to the deep alluvial deposits. Sufficient evidence has been accumulated however to demonstrate that in all probability the range dividing the Ku-yung-kai and Ku-tung-kai valleys is made up of crystalline rocks. Excellent exposures of gneiss were seen in the bed of the Ta-ho, close to the junction of the latter river with the Ku-yung Ho. Granite occurs in the grass and jungle-covered hills which bound the district of Hsi-lien on the west, directly north of Têng-yüeh.

Turning now towards the east, we find exposures of gneissose granite often overlain by andesites, in the high ranges which separate the Têng-yüeh plain from the Shweli valley. On the low broad ridge near Chin-tsai-tang the streams have cut through the andesite covering and have exposed the granite below. On the south, gneissose granite occupies the country as far as the Shweli river, being overlain in places by small patches of eruptive rocks. Further details regarding these occurrences are given in the traverse accounts dealing primarily with the eruptive rocks.

Metamorphic Rocks.

In the neighbourhood of Huan-hsi-po, on the ridge separating the drainage of the Ta-ho and the Ku-yung Ho, a series of white quartzites and fine-grained lustrous phyllites was found. These are similar to phyllitic and slatey rocks folded into the top of the Irrawaddy-Salween divide, which is outside the area under description here, but for which I have already suggested the name Kao-liang series. In appearance they are very like the strata classified as Chaung Magyi in the Northern Shan States and probably they are of the same age. This single exposure is too small to be shown on the map.

The Têng-yüeh Volcanic series.

John Anderson was the first observer to give a general description of the volcano She-toe-shan or, as he erroneously called it, Haw-shuen-shan. Part of this description is given here :—

"In connection with the Nantin (Nan Tien) valley, and very noteworthy, is the large extinct volcano of Hawshuenshan that occurs at its head, and only separated from the valley of Momien (Têng-yüeh) by the little circular valley of its own name. It lies about 500 to 400 feet above the level of Momien, and its base is from 600 to 700 feet above that of Nantin. It runs nearly north and south and is about four miles long, and of an elongated oval form. On its eastern side it is surrounded by flat topped grassy hills, which are generally higher than it, and to the west and north it is separated from the base of a lofty range of mountains by an intervening plain about 4 miles in breadth. It is about 300 feet in height and its summit is an apparently rounded mound, covered with luxuriant grass, while its long flowing sides are a mass of black lava, thrown into long undulations from top to base, or broken up at intervals into heaps, with a few plants growing among the interstices .... The sea of rounded hills to the south and east is forcibly suggestive of volcanic energy, and the occurrence of a small outburst of lava, on the west slope of the Momien valley indicates that disturbing influences must have been felt over a very large tract of country. It doubtless rests on a platform of rocks similar to those found in the Sanda valley and which appear to the east of Momien so that there has been a comparatively recent outflow of basaltic trap over an extensive area composed largely of granite and metamorphic rocks."[1]

L. von Loczy later made a rapid traverse through the Têng-yüeh district and gives a brief account of this volcano. He was the first to recognise the difference in age between the older "ash grey, biotite, amphibole andesites" of the Pagoda Hill near Têng-yüeh, and the felspathic basalt lavas poured forth from She-toe-shan itself.

Other extinct volcanoes which I discovered during the course of the present work are:—

Lao-kuei-po.
Tay-in-shan.
The cones of the Kung-po group.

She-toe-shan.

The area occupied by She-toe-shan and its associated lava fields is an elongated oval, approximately 6 miles in length from north to south and 4 miles wide at its broadest part. The lavas abut on to the alluvial deposits of the upper part of the Nan-tien plain in the vicinity of the market town of Mien-chien, and on the east they overflow the older, bedded, platey andesites around Têng-yüeh,

[1] Report on the Expedition to Yünnan, p. 90.

and the granites of the Pao-fung-tzu range. Looked at from the high ground above Têng-yueh, the crater of the volcano is very distinctly seen rising up from a platform of erupted material, which streams down towards the south, at a much lower angle than on the north. Although She-toe-shan has been quiescent within historical times, nothing could be more evident than its recent appearance. Erosion and denudation have up to the present made little impression upon it. The lava beds which exhibit wrinkled surfaces showing the direction of flow, and radial clefts due to contraction of the cooling material, have no soil upon them on the lower platform, consequently no vegetation except orchids and the hardiest of grasses can flourish. Their surfaces show no weathering and where the flows have crossed and overwhelmed each other, masses of loose blocks of lava are piled up, making progress across the sides of the cone, a matter of difficulty and danger. There is no surface water, for the rain disappears into the bubble holes as soon as it falls. The lower part of the volcano and all the flows around are made up of one type of rock, a black, slaggy, pumice-like material, often full of steam holes and very rarely of a denser nature. Mr. Burton has found these rocks to consist of scoriaceous basalt, and olivine basalt lavas.

I should estimate the height of She-toe-shan above the level of the plain in which it stands to be about 900 feet. The last 300 feet rise up more abruptly, as can be seen from the photograph and sketch, and form the crater itself. The sides are very steep and are covered in places with short grass, and lines of weathering are slightly visible upon them. The steep crater wall does not extend completely round but is blown out somewhat towards the north. To the west, the much denuded slopes of the gneissose ranges running towards the south-west, and shutting in the plains of Nan-tien, are only separated from the lava fields by a narrow belt of alluvial ground, through which the Ta-Ho flows to join the stream from Têng-yüeh, a few miles further to the south (Pl. 10).

Lao-kuei-po.

The extinct volcano Lao-kuei-po lies about 2 miles to the west of Têng-yüeh city and rises to a height of 800 feet above the northern side of the small Ho-shuen-shan plain. The slopes of the cone are very regular with no rock outcrops visible from a distance on its sides, and it was only from the top of the

Pagoda Hill to the south-west of Têng-yüeh that its general shape and a view of part of the crater wall led to its being visited.

The crater wall is almost circular save where it is blown out on the west side overlooking the Mien-chin plain; through this shallow opening the long, slaggy lava fields of the south-eastern slopes of She-toe-shan can be seen, backed by high gneissose ranges. The crater itself is about 100 feet deep and 200 yards across, and is best approached by climbing up the precipitous side of the volcano, which towers above the Chinese village of Ta-chuan. The lower slopes are clothed in pine forest, and higher up, thick grass hides all good exposures of rock. The small outcrops which were found consisted always of a very light pumice-like rock, so full of steam holes that small pieces were found to float on water. From the greater denudation that it has suffered, it is evident that Lao-kuei-po is older than She-toe-shan.

Tay-in-shan.

The volcanic origin of this hill which forms such a prominent feature of the landscape to the north of Têng-yüeh, was first suspected by Loczy, from its general outlines; even from a great distance away its long sloping sides are clearly visible (Pl. 9 & 11). Loczy however did not visit the hill. It lies 8 miles to the north-north-west of Têng-yüeh, and rises to a height of 9,400 feet above the sea, and some 3,250 feet above the general elevation of the Têng-yüeh plain. It is entirely composed of black, slaggy, pumice-like lavas which continue from base to summit. In appearance they are practically identical with the lavas of She-toe-shan, and the area which the later flows cover is much the same, though more circular in outline. At the base the slaggy black lavas are seen in contact with the underlying granite. The ascent is easy at first but it becomes more difficult higher up, because the independent lava beds have a tendency to end off in wall-like escarpments which have to be negotiated with some care. The flows arrange themselves in platform-like structures which are not clearly seen from a distance, and it is from one of these that the cone rises. The crater wall is missing on the south-east side, thus giving to She-toe-shan the double-topped appearance it possesses when viewed from the south.

The Kung-po Volcanoes.

I have given this term to a group of small craters of the "Puy" type, from the name of the sub-division of the Têng-yüeh district in which they are situated, which lies some 12 or 13 miles to the north-east of the city. Looking south from the high ground to the north of Ku-tung-kai, (a small market town 22 miles north of Têng-yüeh), no less than 7 small craters can be seen, excluding Tay-in-shan (Pl. 12).

The three more important of these can be conveniently visited from Ma-chan-kai, a Chinese village approximately half way between Têng-yüeh and Ku-tung-kai. The most southerly rises gently from the plain to a height of 150 feet approximately, and consists of an almost circular wall, with a deep crater hollow inside. Owing to extensive cultivation, no rocks are visible (Pls. 8 & 15).

The middle hill 6,600 feet in height above sea level, attains a height of 700 or 800 feet above the surrounding plain, and is very much steeper than the former one. Its crater is a little smaller and not so deep. Long grass with a few scattered pine trees covers it on all sides, but a few exposures of a pumice-like lava were obtained. The most northerly of the group appears to be younger, for its separate flows are clearly visible, and are only clothed with a thin scrub jungle. The crater itself is 300-350 yards across and its wall is blown out on the north and south. The lava beds of this volcano are very like those of Tay-in-shan, and appear in places to have overwhelmed the alluvial and lacustrine deposits of the valley, which are cultivated up to their edges. Another hill to the north-north-east has the same truncated and inverted conical appearance with the inner edge of its crater wall showing. These volcanoes are too small to be shown independently on the map in my possession, so the area covered by their latest ejectamenta has been coloured. It is approximately 3½ miles long and 2 miles broad at its widest part.

The probable existence of other centres of eruption.

The mountain Yao-wu-shan (7,200 feet), to the north of Ku-tung-kai has all the appearance of an old volcano, but its sides are grass-grown and there are no rocks visible. The high peak Lutsung-shan (8,800 feet), visible from Têng-yüeh may be of similar origin. I am informed by Mr. George Forest who accompanied the late Consul, G. A. Litton, into areas lying north of those traversed by myself, that hills of crateriform aspect were met with on their journey, and it is probable that extended examination will reveal further volcanic foci in this direction.

The older bedded andesites.

The eruptive rocks of these volcanoes are more or less confined to small areas around them, and over which they were poured in late Pliocene or even Pleistocene times, when the general orography of the district was much the same as it is at the present day. This is proved by the recent appearance of the craters and of the rocks themselves, by the fact that they have taken part in no earth movements and are not tilted, folded or crushed in any way, and also that in Kung-po at least and possibly elsewhere, they have poured out over the late Tertiary lacustrine deposits of the valleys close to which they are situated.

But it is certain that the very ancient, ash-grey, greyish-blue and occasionally reddish-grey, close-grained, porphyritic andesites which have a characteristic platey structure and which are often folded, belong to a very much earlier period. Wherever these rocks are found they always underlie the later ones and come between them and the crystalline floor.

The massive andesite group.

Distinct from the older bedded andesites and from the newer slaggy lavas, is another series of eruptives which are generally of a light grey, trachytic nature, sometimes solid and sometimes with a well developed pumice-like structure. From the incomplete evidence at our disposal at present, it is believed that the vents of the older platey andesites have long since been removed by denudation, and that they were probably erupted in some far away geologic period, for their distribution bears no relationship whatever to the present lie of the land, and their appearance vividly recalls some of the palæozoic andesites of Great Britain. Again, it is certain that they have taken part in the Tertiary earth movements which were largely responsible for the distribution of mountain and valley in this part of the world at present.

The massive andesites are older than the black slaggy lavas associated with the vents which exist to-day. Sometimes, rocks of this series are found in direct contact with the old crystalline floor, which circumstance is explained by assuming, either that the older folded and platey andesites did not originally reach these particular places, or that they were removed by denudation before the later ones were erupted.

Eruptive rocks to the north and north-east of Têng-yüeh.

The northern route leaves Têng-yüeh at an elevation of 5,450 feet and after crossing the river, commences the ascent of bare hills which extend to the foot of the Tay-in-shan—Lu-tsung-shan range. Although exposures are hard to obtain, it is believed that these hills are entirely made up of the older bedded andesites. Near the fourth mile the lavas of Tay-in-shan are first encountered, and the ascent becomes steeper up a narrow valley to a pass on the low saddle which separates the spurs of the two peaks. The small stream which flows down the pass, marks the junction of the old andesites with the younger lavas of the volcanic cone to the west. These andesites are very contorted, in places possessing a vertical dip, and they are unconformably covered with the practically horizontal Tay-in-shan lava beds. The andesites weather down into a red tenacious clay which forms a stiff and unproductive soil. The road now commences to gradually descend through fir woods still keeping in the same general direction. Near the bridge at the small village of Hsiang-shui-kou the andesites strike west-south-west, east-north-east and dip south-south-east at 22°.

The greater part of the valley which is now entered is filled with alluvium partly occupied by a paddy plain. It is underlain however by slaggy, pumice-like, recent lavas judging from the outcrops found on the ground above the paddy plain level, over which the road crosses. In places the extreme porosity of the stone below causes the tramping of men and mules to make a dull, muffled sound, although no outcrops may be visible. When the latter are seen below the soil with its covering of thin scrub jungle, they look exceedingly fresh and the lines of flow have a north-easterly or north-north-easterly direction. It was found to be impossible to map these flows which are probably the earlier outpourings of Tay-in-shan, on the small scale map, and the volcanic rocks of this centre of eruption as shown, only represent those of the latest generation.

As Ma-chan-kai is reached the group of small volcanic craters described in an earlier paragraph come into view, and the road crosses another paddy plain to the large village of Shun-shiang, 17 miles from Têng-yüeh. The boundary hills to the west of this place are composed of a coarse gneissose granite, consisting of a very decomposed white felspar with quartz in about equal amounts, and a little biotite mica. Further to the south near Po-shang-tsun, this gneissose granite has been much metamorphosed by the heated lava flows which have come on to its upper surfaces, so that the rock now consists of a soft reddish material with the quartz remaining as the only recognisable mineral. It is probable that the two hills to the south-east of Po-shang-tsun are composed of granite, standing out as islands in the lava plateau.

The last of the well defined flows is seen just beyond the village of Shun-chiang, where it overwhelms some of the valley deposits. Near Ku-tung-kai great thicknesses of alluvium hide all outcrops, but to the north on both branches of the road, one of which leads into Ming-kuan and the other into T'ien-t'aung-kuan, the old bedded andesites occur again. These rocks appear to make up the whole of the mountain Yao-wu-shan, which attains a height of 7,200 feet above sea level. Near the village of Yao-wu-shan, which lies on the lower northern slopes of the mountain of the same name, the andesites strike east and west and dip to the south at 35°. Further to the north however the strike veers round more towards the north. In the T'ien-t'aung-kuan near a small village Hai-tang, which lies a few miles to the south of Ying-pan-kai, the last outcrops of decomposed, porphyritic, grey, platey andesites were found, which in appearance resembled the Yao-wu-shan rocks exactly. To the north of this point, and in the upper parts of the Ming-kuan as far as they were traversed, gneissose granites and crystalline limestones were the only rocks met with.

Returning to Ku-tung-kai and marching south-east into the Shweli valley at Chü-ch'ih, and thence south-west to Têng-yüeh again, many sections of the eruptive rocks were obtained. For the first few miles the open grassy downs which border the plain on the east were traversed, but where the road crosses the river by a bridge, there are excellent exposures of the massive andesites.

For some miles beyond this point the road crosses grassy uplands which are partly cultivated and partly covered with sparse pine woods. The river flows in a rocky gorge the general direction of which the road follows. There is only a thin soil covering and the massive lavas frequently pierce through this to the surface. It is possible that some of these may belong to the more recent outbursts of the Kung-po group, but only detailed petrological examination and mapping on a large scale could definitely settle this. Between Shan-chang and Chü-ch'ih decomposed gneissose granite was observed on the higher ground, overlain down in the valley by decomposed bedded andesites.

Massive andesites are found between Chü-ch'ih, which has an elevation of 6,550 feet, and the Shweli crossing at 4,900 feet. Similar rocks outcrop in the bed of the river.

Between Chü-ch'ih and Têng-yüeh massive andesites continue to the large tributary of the Shweli which is crossed at the second mile, but here they are replaced by the older bedded group which in places have more the appearance of tuffs than is usual. From this point up to the top of the divide which separates the drainage of the Shweli from that of Taping there are practically no exposures, but just beyond the pass and close to the Hai-kou lake, a small outcrop of greyish-white, massive andesite was found. The village of Hai-kou has an elevation of 7,300 feet and just below it, the old bedded andesites are found in good exposures, exhibiting considerable contortion. The best examples of this structure are to be seen near the village of Fu-i-tsun overlooking the Têng-yüeh plain. The small outcrop of the massive andesite found near the pass at an elevation of 7,700 feet, lies above the ancient, bedded, platey andesites and may represent the remnants of a former much wider-spread sheet.

Excellent examples of the massive andesites are obtained in the quarries near the residence of the Commissioner of Customs, and just below the waterfall at Têng-yüeh. The walls of the city which are of considerable magnitude are constructed of the same rock, which makes an excellent building stone.

Eruptive rocks on the east of Têng-yüeh.

On the east of Têng-yüeh, volcanic rocks continue almost as far as the Shweli river, that is to say for a distance of 15 miles.

The direction of the traverse was along the main track to Ta-li Fu, in a general east-south-easterly direction. The road crosses the Tertiary and alluvial deposits of the plain by a raised causeway paved with blocks of andesite. A steep zigzagged ascent of the hills which bound the valley commences at 3 miles, and in the next 2 miles attains a height of 2,000 feet above the plain. There are a few exposures of the bedded andesites on the way up, but after the road has reached the top and on to the undulating plateau which is then met with, exposures are poorer. It is indeed doubtful if there is anything more than a few small isolated outliers of the older andesites just here, and the greater part of the neighbourhood appears to be made up of gneissose granite, which has weathered into low rounded hills with broad V shaped, branching valleys between them.

Near Chin-tsai-tang massive andesites rest on the crystalline rocks, and in many of the smaller stream beds sections exhibiting these relationships are to be found. In the stream bed at Kan-lan-ssu, 2 miles beyond Chin-tsai-tang, the massive andesites weather out in large spheroidal masses. After passing this place there is a slight rise to 6, 800 feet, when the steep descent to the Shweli commences. The road crosses granite and gneissose rocks but only very poor exposures were found. The village of Kan-lan-chai is reached at 13 miles (7,800 feet), and from it there is a steep descent to the Shweli at 13 miles, (4,200 feet). Although the road is paved with blocks of massive andesite it is not by any means certain that they extend much beyond Kan-lan-ssu. This can only be settled by traverses to the north and south.

Traverse to the south of Têng-yüeh.

The flat Têng-yüeh plain stretches south for 7 miles, but exposures of rock are to be obtained in the low foot hills, especially on the east side. In a stream bed 1½ miles to the east of Ta-tong for example, dark granular andesites of the massive group outcrop. After the route leaves the plain there is an easy ascent of 1,000 feet up to the top of the divide, which has an elevation of 7,000 feet, thence, there is a long descent to a narrow, alluvial-filled valley which contains the villages of Shang-chia-chai and Mong-lien. The bare hill sides over which the road has crossed are completely grass-covered and there are no good outcrops, but it is probable that the greater part of this area is made up of granite and gneissose rocks. Near Mong-lien however there is a small outlier of decomposed andesites, lying on the surface of the granite, but it only continues for a few hundred yards. After leaving this little valley the road commences to ascend a ridge along which it winds and undulates. The whole of the neighbourhood is clothed in primeval forest and occasional glimpses are obtained through the trees across the Shweli. Descending the other side of the ridge, there are no exposures up to within a few hundred yards of Chang-kang, where decomposed andesitic lavas are found. From the character of the outlines of the hills and the nature and colour of the soil, it is evident that gneissose rocks make up the whole of the surrounding country, and here as elsewhere form the foundation over which the later rocks have been poured.

The road now winds along the crest of the ridge overlooking the Shweli in a general south-south-easterly direction. Near the village of Man-chi, 30 miles from Têng-yüeh, (elevation 4,800 feet), there is a large outlier of massive andesite of a tachylitic appearance and black colour. Greyish-white, massive andesites also occur here, and further to the south in the vicinity of Man Lu. Descending to the Shweli the road runs through pine forest, the path being edged with rows of gigantic cactus. In the alluvium and detritus filling the valley of the river, large rounded boulders of gneiss and mica schist were seen, and similar rocks were found in the stream bed itself. Beyond the Shweli no further outcrops of eruptive rocks were discovered, the country as far as the town of Lung-ling being made up of crystallines.

Eruptive rocks to the east and south-east of Teng-yueh.

Leaving the city by the west gate and following the Ho-shuen-shan road, the Têng-yüeh stream is crossed near the waterfall, where the strike of the granite which underlies the massive lava exposed here, is north-east, south-west. After recrossing the stream again in the lower valley, the junction of the She-toe-shan lavas with the granite is well exhibited, thence the road continues on to the older bedded andesites, good exposures of which can be obtained. This rock forms the high bluff to the north-east of the village of Hsiao-hoti Ho, and it is also characterised by the bright Indian red soil into which it weathers down on the hill sides. Below Hsiao-hoti Ho the stream enters a narrow rock-valley full of rapids and small falls, made up of the outcrops of lava beds of the massive variety. Good sections can be obtained in this narrow gorge, and in places there appears to be a well marked columnar structure developed. Higher up there is a flat expanse which continues across to the other stream coming down from the Mien-chien direction. Beyond this point the older, ash-grey andesites continue to outcrop at intervals as far as Jê-shui-tang, just to the north of which the Têng-yüeh stream leaves its narrow rock-bound valley, and joins the Mien-chin one. Looking upwards from this point the more recent flows of She-toe-shan are very well seen.

Late Tertiary Lacustrine Deposits.

True lake deposits usually made up of loosely cemented beds of gravel and pebbles, silts, sandy shales and sand-rock are found throughout the whole province of Yünnan, and their actual formation has in a few places been prolonged down to the present day, for some of the plains still contain lakes which are very evidently the last remnants of more extensive sheets of water. The deposits are always the result of the denudation of the surrounding formations, and are generally chosen as the sites of the walled cities of the province, as the soil formed from them is very fertile. Concerning them Lantenois has well remarked,—"Presque toujours bien arrosées et, partant bien cultivées elles présentent un aspect de richesse, un air riant qui contraste avec l'aridité et la pauvreté des montagnes voisines. Le colmatage des lacs anciens, commencé à l'époque tertiaire, se poursuit sous nos yeux; les lacs d'aujour-d'hui ne sont visiblement que le vestige de ceux d'autrefois, qui furent plus profonds et plus nombreux."[1]

Similar deposits are well known in the Northern Shan States and in Tongking. The former have been described by La Touche and Simpson, as silts and soft sand-rock, pebble and boulder beds, and seams of brown, lignitic coal, found in detached areas occupying the present river valleys. Shells of fresh water gastropoda have been found in these deposits, which are of such a

[1] H. Lantenois, "Résultats de la mission géologique et minière du Yunnan Méridional," *Annales des Mines*, (10), XI, 1907, p. 300.

type as to indicate an extremely late Tertiary or perhaps even Pleistocene age.[1]

Zeiller, from a study of plant remains collected in the lacustrine basin of Yen-bay (Red River Valley, Tong-king,) regards the strata as Mio-pliocene in age.[2] Loczy found freshwater limestones in the north of Yünnan which he thought were of Pliocene age, and Leclére considered the deposits of the C'hu-shuing Fu plain in Central Yünnan to be of Tertiary age.[3] Mansuy found a *Paludina*, showing a marked resemblance to the *Paludina* (*Tylotoma*), occurring at Yen-bay, Tongking, in lignite bearing shales of the Tertiary basin of Mi-la-ti near Möngtzu, Yünnan; and *Planorbis*, *Paludina* and *Bithynia* were discovered by the same geologist in the lacustrine beds of Pou-tchao-pa near A-mi Chou, Yünnan.[4] In a greyish fine-grained silt which forms part of the old lake deposits of the Yung-ping Hsien plain, I have collected numerous crushed remains of a small gastropod, probably referable to the genus *Bithynia*, and in the stratified deposits above the present level of the K'un-yang lake near Kun-yang Chou, I have noticed abundant remains of a *Margarya*, a genus which is one of the commonest molluscs in the living fauna of the present lake. These occurrences are noted here because no fossils have been found in the lake deposits which are described below, but as they are in every other way identical, we are forced to the conclusion that at no very remote period, practically all the valleys of Yünnan were occupied by lakes, some of which still exist, whereas others are only known by the series of sediments accumulated in them.

The Lacustrine deposits of Kan-ngai, Nan-tien and other plains.

The Kan-ngai plain, (Lat. 24° 47′ : Long. 98° 8′, height above sea level 2,900 feet), extends on both sides of the Ta-ping from 7 or 8 miles above its junction with the Nam-ti down to where the river enters the gorge below Man-hsien, a total length of about 38 miles

[1] T. D. La Touche and R. R. Simpson. "The Lashio Coal Field" *Records Geol. Surv. Ind.*, Vol. XXXIII, Pt. 2.

R. R. Simpson, "The Namma-Mansang, and Manselo Coal-Fields;" : *Ibid*, p. 125.

[2] Zeiller, Congrés geologique international, Paris 1906; pp. 168 and 498-561.

[3] Leclére "Étude géologique et minière des Provinces chinoises voisines du Tonkin," *Annales des mines*, (9) XX, 1901, p. 323.

[4] Mansuy in Lantenois' paper, *loc. cit*, p. 469.

running approximately from south-west to north-east. The whole of this area was once filled with lacustrine deposits, which are now best observed in the high terraces through which the river has cut its way just below the Hu-lu-ko gorge, and which are the remains of a once more extensive covering. These are about 70 feet in height and are composed largely of soft sand-rock and rubble. Throughout the greater part of the valley there is much recent fluvio-lacustrine material consisting of the reassorted and redistributed sands and gravels, of which the higher terraces are formed, removed by the denuding action of the river.

The Nan-tien plain, (Lat. 24° 49′ : Long. 98° 22′, height above sea level 3,600 feet), extends for some 15 miles down the Nam-ti and exhibits the formation of the terraces in a better manner than the Kan-ngai one (Pl. 14).

Looking to the south-west from near Jê-shui-tang at the head of the valley, a well marked terrace is seen rising to a height of 80 or 90 feet approximately, and further to the south there is a corresponding one on the other side of the river. These are composed of the usual kinds of materials, and their sides are much weathered into small gullies. As the road to the south-west is traversed both terraces are seen to maintain their approximate height, while the level of the paddy plain, which represents those parts of the lake deposits removed by the river, keeps a more or less uniform width. Below Nan-tien the terrace on the northern side meets the spurs of the hills which here close in towards Hu-lu-ko, and consequently dies out, but there are still small outlying fragments of it to be seen further south, specially from the high ground above the Hu-lu-ko gorge. The southern terrace maintains its well marked character, and as the valley drops it appears to become more elevated, so that a few miles below Nan-tien it is twice as high above the river as it is at Jê-shui-tang. Around Se-tau, however, it is much broken and denuded though the isolated pieces still maintain the same general height. Recent landslips about here have exposed yellowish and white sandy beds and sand-rock, with lignitiferous shales in places, but the best sections are exposed one to two miles to the north-east of Nan-tien town, where numerous side streams have excavated deep valleys with preciptious sides in the terrace. These sections show beds of sand loosely held together, pebble beds which being slightly cemented have the appearance of conglomerates, yellowish and bluish clays with bands of carbonaceous shale containing fragments of lignite.

These and other detached basins not only in Yünnan but in the Northern Shan States of Burma, must have formed an assemblage of lakes when the land stood at a relatively lower level than at present. Some of the existing broad valleys were either completely filled up with lacustrine and fluvio-lacustrine deposits, or earth movements took place which resulted in their drainage before this was accomplished. The rivers, or at any rate those on the Chinese side of the frontier are now engaged in excavating their beds in the old deposits.

The Lo-po-ssu-chuan valley is also filled with similar deposits, which near Lai-fu consist of sandy beds and layers of bluish clay, thin bands of carbonaceous lignite-bearing shales also occur, but the material is of no economic importance.

Similar strata are found in the Möng-wan valley which forms a small Chinese Shan State, (Lat. 24°, Long. 97° 59′, Height above sea level 3,100 feet), called Lung-ch'uan by the Chinese, and Mowun by the Burmese. It is situated on the Nam-wun, a tributary of the right bank of the Shweli. The plain itself is about 20 miles long, 6 miles wide at the south-west end, and 1 mile at the north-east end. The whole of this, however, is not filled with lacustrine deposits as is so often the case, for low grassy spurs from the hills around occupy much of the flatter ground, especially at the south-west end.

To the north of Möng-wan lie the twin States of Ho-hsa, and La-hsa, (Lat. 24° 27′: Long. 97° 56′, Height above sea level 4,500 feet), and here again the same phenomenon is visible. Both States lie in the valley of the Nam-hsa, which running down from the hills to the north-east forms a plain 14 or 15 miles long, and from 1½ to 2 miles broad, narrowing however at each end. The eastern half of the valley is occupied by Ho-hsa and the western half by La-hsa. The lacustrine deposits are characterised by an usual development of bluish clays and thin subordinate sandy beds. John Anderson who visited the valley in 1868, noted that if the present exit of the Nam-hsa, where it breaks through to join the Ta-ping was closed, the whole valley would be submerged several feet, and he was not far from the truth when he wrote,—" The study of these clayey beds forcibly suggested the conclusion that they had been deposited in still water, and it is probable that the valley was a lake or swamp prior to the time the Namsa found an exit for itself through the hills to the west, or one of sufficient capacity to admit of the free drainage of this mountain basin.''[1]

The lacustrine deposits of the Têng-yüeh valley contain abundant beds of peat, which is black, somewhat compressed and with the remains of thin roots and stalks of plants preserved in it. Under the alluvial soil and loam, thin layers of yellowish-grey clay are usually found underlain by lighter sandy beds, made up almost entirely of small, clear quartz grains with a few milky grains of felspar. Under the sandy beds the peat comes in. Little can be added to Anderson's expressive description of the deposits, which is therefore reproduced here. "Below the soil, which is about one foot in thickness, there is a reddish ochreous earth of very light weight and of about 8 inches deep, resting on a bed of black peat, about 4 feet thick in some places, and overlying a light coloured consistent clay of considerable depth, filled with little water-worn particles of white quartz. The clay is largely used in the manufacture of bricks. The probability is that the Momien valley, through some disturbance in its level immediately after the formation of the lowest bed, was converted into a shallow marsh; then followed another change in its level, indicated by the reddish ochreous earth, and the valley was once more converted into a lake. There can be no doubt that the Taho has itself done much in altering the character of the valley, for it is impossible to look at its narrow exit, and at the aspect of the hills between which it flows at that spot, without the conclusion forcibly suggesting itself that the river has done a gigantic work in the way of cutting a passage for itself between them, and that their configuration is in great part to be attributed to its eroding action. A careful examination of the glen below the fall reveals the fact that the river is slowly but gradually bringing the waterfall more and more to the east. Standing to east of the low conical hills which close in the valley at this point, the theory suggests itself that the valley must at one time have been a deep lake, with a depth corresponding to the conical hills, and that its waters, draining out as a small stream into the valley below, slowly deepened their channel every year, reducing the level of the lake until at last it ceased to exist, and the Taho, that had fed it, flowed through it, and began to disintegrate the slope to the Hawshuenshan valley, and to form a waterfall when

[1] J Anderson. *loc. cit.*, p. 83.

it came in contact with the mass of basalt that forms the Momien plateau. The slow wearing away of the hills at the exit of the lake could have in no way affected the nature of the deposits, the differences in which can only be accounted for by the changes in the relative levels of the valley. The bank at the base of the hills, which slope gradually to the level flat of the valley, seems to favour the foregoing view of its history."[1]

Although Anderson may not have got the fluctuations to which the lake level was subjected during the later days of its existence, in their true chronological order, the main outstanding points in its history as here given are correct in the light of later evidence which has been collected since his day.

Hot Springs.

Any account of the geology of the Têng-yüeh district would be incomplete without some reference to the numerous hot springs found in it, which are supposed to represent the last manifestations of the vulcanicity which has been so intense in Tertiary and, perhaps, later times. Hot Springs occur at:—

(1) Hai-tang near Ying-pan-kai, T'ien-t'aung Kuan district, where boiling water issues in two places, the first just below the spur on which the village is built, and the second 400 or 500 yards towards the west. In the case of the latter, the water bubbles up from many openings over a space of 20 or 30 square yards. The water is heavily charged with salts and each small opening forms a tiny craterlet for itself: judging from the numerous small dry ones in the immediate neighbourhood, the springs must shift their positions from time to time.

(2) Hai-lung-tang, 4 miles to the south-south-west of Têng-yüeh. There is a copious discharge of boiling water from a single large craterlet at this place into a basin which the spring has formed for itself by the deposition of siliceous sinter. Jets of steam and other hot gases are given off from numerous openings round about, and the evolved heat is great enough to prevent the near approach of barefooted men. A distinct vibration of the earth is also noticeable. Some of the gas vents deposit small quantities of native sulphur which at one time was collected by the local Chinese for the manufacture of gunpowder. The waters are said to be

[1] J. Anderson, *loc cit.*, pp. 91-92.

possessed of curative properties and are led away in rock channels to baths, which are the resort of numerous patients afflicted with skin diseases.

(3) Jê-shui-tang. Here the hot water issues in two distinct places, approximately 400 yards to the east of the village. The one to the north is the larger and gives out sufficient fluid to form a small stream, the stones in which are coated with deposited salts. The other opening appears to deposit more solid matter and has built up a small crater wall over which the hot water trickles. Both places betray their exact position by the evolved steam they give off. It is interesting to note that although the water is scalding hot a few yards from the orifices, the stones in it are covered with masses of a bright green alga which appears to flourish even at this high temperature.

(4) Sanda. I have not visited these springs, but they have been described by Anderson who says that they occur in the centre of the level flat of the bay-like vale close to the town. The flow of water is not very great, and it bubbles up through round holes in a black micaceous sand. The same traveller also crossed a hot stream between Muangla (Nan-tien) and Sanda, but did not find the source of the heated water.[1]

EXPLANATION OF PLATES.

PLATE 6.—Panorama. The Têng-yüeh valley from the west.
PLATE 7.—Panorama. The Ho-shuen-shan valley from the east.
PLATE 8.—Two typical craters of the Kung-po group.
PLATE 9.—Tay-in-shan from the north.
PLATE 10.—She-toe-shan from Pagoda Hill.
PLATE 11.—Tay-in-shan and associated hills from the south.
PLATE 12.—The Kung-po group of craterlets looking south from Yao-Wu-Shan.
PLATE 13.—The Waterfall, Têng-yüeh.
PLATE 14.—Late Tertiary Terraces. Nan-tien Plain.
Ditto. ditto. (near view.)
PLATE 15.—One of the Kung-po Volcanoes.
Typical alluvial plain of Kan-ngai Valley.
The Hu-lu-ko Gorge separating the Chinese Shan States of Kan-ngai and Nan-tien.
PLATE 16.—Map illustrating the Geology of the country between Bhamo and Têng-yüeh. Scale 1" = 4 miles.
PLATE 17.—Map illustrating the former course of the Irrawaddy before the formation of the second and third defiles. Scale 1" = 16 miles.

[1] J. Anderson. *loc. cit.*, p. 82.

CONTRIBUTIONS TO THE GEOLOGY OF THE PROVINCE OF YÜNNAN IN WESTERN CHINA. (II). PETROLOGY OF THE VOLCANIC ROCKS OF THE TÊNG-YÜEH DISTRICT. BY R. C. BURTON, B.SC., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 18 to 20.)

The volcanic rocks of the Têng-yüeh area have been divided by Mr. Coggin Brown[1] into three groups which will be described in order :—

Newer Lavas.

1. Basalt lavas of Tay-in-shan, Ho-shuen-shan and the Kungpo group of volcanic vents.

Older Lavas.

2. Massive Andesite group.
3. Bedded Andesite group.

Very little is known about the field relationships of these lavas, and of the separate flows composing each group, but it may be stated that the andesites are older than the basalts, and that the rocks of the third group are the first products of the eruptions.

1. Basalt Lavas of Tay-in-shan, etc.

These are the latest volcanic rocks erupted in the district from the various late Tertiary cones described by Mr. Coggin Brown. Similar rocks have been partly described by Loczy and Koch.[2]

They are vesicular black rocks passing in some cases into a reddish pumice which floats on water; on a fractured surface they have a glistening slaggy appearance. The vesicles are numerous and are never filled with secondary minerals, testifying to the late Tertiary age of the group, for even the Tertiary lavas of the Icelandic Province have their vesicles filled in with secondary minerals.

[1] J. Coggin Brown "The Bhamo-Têng-yüeh area" *Rec. Geol. Surv. Ind.*, Vol. XLIII, pp. 173-205. All the rocks now described were collected by Mr. J. Coggin Brown during journeys mentioned in the paper quoted.

[2] In Graf Bela Szechenyi's Reise in Ostasien, Vol. III, p 379.

The texture varies from place to place, and even in the same rock specimen a passage may be traced between a scoriaceous lava with bubble holes, to a compact black rock with few vesicles to be seen.

21·691; 9690. LAVA FROM KANG-CHE-CHOW. S.G.=2·51.[1]

Fine grained black basalt, slightly vesicular and containing phenocrysts of glassy felspar, brown pyroxene and yellowish olivine. The porphyritic felspars are quite fresh and undecomposed but strongly corroded by the groundmass; they are sometimes free from inclusions, but often contain a zone of glassy matter and magnetite, surrounded by a narrow area of later felspar material. (Plate 18, fig. 1.)

The augite is of a light brown colour, non-pleochroic and much fractured, many of the crystals are corroded and some show a kind of schiller structure.

The olivine occurs sparingly in large crystals which are quite fresh and show good pinacoidal cleavages.

The groundmass contains but little clearly visible residual glass: it is in great part obscured by fine magnetite dust, which prevents a close examination being made. The felspar laths are chiefly andesine and labradorite; light brown augite grains and magnetite are numerous, but do not require further description. A distinct flow structure is seen in the parallel orientation of the felspar laths. Some of the vesicles contain partly devitrified glass in the centre, with felspar microliths radiating from the walls into the glassy matter, and the interspaces between them are filled with a light brown glass.

The chief characteristics of these rocks are the strong zoning of the felspars, and the large number of yellowish glass inclusions they contain. A few glomero-porphyritic aggregates of felspar and augite occur but these are more characteristic of the andesites to be described below.

The percentage of silica in most of the rocks appears to be high. Rock No. 21·691 on analysis yielded 53·30 per cent. SiO_2—much more than the average basalt contains, but high acidity seems to be a characteristic of the Têng-yüeh lavas.

[1] All specific gravities were determined on hand specimens. 21·691, etc., are register numbers in rock register. 9690 etc., are register numbers in microscope slide register of the Geological Survey of India.

21·164; 9682. OLDER PUMICE FLOW, HO-SHUEN-SHAN.

This rock is worthy of special description. It is a real pumice coated on the surface with ferric oxide probably due to superficial decomposition. It is full of vesicles and floats in water. Scattered groups of augite and felspar occur, the latter being usually filled, or strongly zoned, with glass. The ordinary glass of the groundmass is a reddish colour but patches of colourless glass containing magnetite dust are included in it. The olivine crystals are fairly fresh, but usually corroded round the edges. The large yellowish green augites are fractured and filled with hæmatite. Radiating structures typical of basalts are frequently met with: several felspar laths develop from a centre round which augite has collected, filling in the spaces between the crystals, and the growth of these two constituents has been practically simultaneous.

9686. HO-SHUEN-SHAN.

A basalt lava from the middle of the slope of the Ho-shuen-shan cone contains some interesting felspars. In two or three cases the felspar has been corroded by the magma and is now circular, surrounded by a kind of reaction rim composed of yellowish needles of augite which radiate from the outside edge. This is finally surrounded by the groundmass which is nearly opaque, due to magnetite dust. The needles of the rim are difficult to determine, but judging from their extinction angles and double refraction colours they seem to be augite, probably formed by a reaction between the felspars and the glass of the groundmass. J. F. Kemp in his paper on the gabbros of Lake Champlain [1] mentions reaction-rims occurring between felspars and olivine, hornblende, etc., but no mention is made of a rim similar to the above.

It is interesting to compare these rocks with others of similar age. T. D. La Touche [2] has described a Tertiary basalt from the Northern Shan States, and compares it with the lava from Ho-shuen-shan, described by Loczy, which has been seen to be similar to the lavas of Tay-in-shan and the Kung-po vents. He concludes that there is a great resemblance, except that the Chinese rocks contain a glassy base while that from Loi Han Hun, being a dyke rock, is devoid of glass. On examining

[1] *Bull. Geol. Soc., America*, Vol. V. (1894), p. 218.
[2] *Rec. Geol. Surv., India*, Vol. XXXVI (1907), p. 40.

La Touche's slide, I found it to show a closer resemblance to some of the light-coloured olivine basalts of the massive andesite group, than to the black basalts of the last stage of eruptions. It seems probable that these Shan rocks are of the same age as the Têng-yüeh series which are of late Tertiary age. Loczy was of the opinion that the basalt lavas were erupted during the diluvial period.

2. The Massive Andesites.

These rocks are an earlier, more acidic series of lavas than the basalts forming the vents of Ho-shuen-shan, Tay-in-shan, and the Kung-po group. The vents from which they were erupted are not definitely known, though Loczy seems to have assumed that they came from the same source as the basalts, but no definite evidence was obtained proving this; in addition, Mr. Coggin Brown has found them entirely dissociated from the latter and is of the opinion that the vents from which they issued are now hidden from view.

They may be divided into the following types:—

(1) augite andesite, sometimes amygdaloidal.
(2) olivine-augite andesite.
(3) olivine basalt (light-coloured).
(4) enstatite-augite andesite (pyroxene andesite).
(5) andesite glasses.
(6) amphibole andesite, in some cases containing nepheline.

26·161; 9671. FROM KAN-LAN-SSŬ. S.G.=2·58.

Augite Andesite.

This rock is a spherulitic augite andesite of a fresh appearance in the hand specimen, dark-grey in colour with a few glassy felspars in a microcrystalline base; a few vesicular cavities occur which have not been filled with secondary minerals, pointing to the fairly recent age of the rock.

Under the microscope it is fine-grained and of a brownish appearance owing to the distribution of a partly devitrified, dull brown glass, which occurs in spherulitic aggregates and is also distributed between the felspar laths; the groundmass is hyalopilitic and the ordinary glass is colourless. The porphyritic felspars are for the most part labradorite and are quite fresh; they are frequently fractured and sometimes bent round to form a re-entrant angle of 130°; in such cases the strain is accompanied by intrusion of a light yellow, devitrified glass traversing the crystal at right angles to its longer axis; and the extinction of such felspar crystals is wavy.

The augite phenocrysts are of a light brown colour, irregular in shape with a ragged edge due to magmatic corrosion; they are in some cases surrounded by brown spherulitic glass. They are often fractured like the felspars and contain brown spherulitic glassy inclusions, which are separated from the augite material by a dark border containing magnetite. This brown glass[1] sometimes encloses within it a layer of pure white glass, the whole having an amygdaloidal structure. Magnetite is common in the groundmass as irregular grains.

26·160; 9673. STREAM NEAR JÉ-SHUI-TANG. S.G.=2·68.

This rock is in general texture similar to La Touche's basalt from Loi Han Hun, but is more acidic, containing a larger proportion of felspar and magnetite and less augite. It is a dark-bluish rock with small felspar laths set in a finely crystalline base. Under the microscope it is seen to be an andesite, with but little glassy base: in fact the ground mass is so much obscured by magnetite and opacite that the certain detection of a glassy base is impossible. The peculiarity of the rock as compared with the others is that all the felspars approximate to the same size, and the large felspars usually present in the andesite are absent, it has more the appearance of a dyke rock than of a lava. By far the most important constituent is the felspar which occurs in lath-shaped crystals of andesine and labradorite. They are much corroded by the groundmass and contain a line of black or yellowish granular inclusions which follow the outline of the crystal a short distance away; these inclusions probably consisted originally of glass from which the magnetite has now separated. Other inclusions consist of a yellowish substance, which is pleochroic and gives colours of the second order; it is probably interstitial glass devitrified into augite and felspars, the latter having crystallized out in continuity with the containing crystal. Magnetite is common, giving a dark colour to the groundmass, but it rarely occurs in crystals. The felspar laths show a well developed flow structure.

[1] This glass resembles in some respects the so-called palagonite of the Rajmahal Traps. See C. S. Middlemiss *Rec. Geol. Surv. India*, Vol. XXII, p. 226.

The augite occurs as small, light-brown irregular grains between the felspar laths, but is a much less important constituent of the rock than the latter. Some interesting examples of elementary crystallisation also occur. Long non-terminate rods of augite, and colourless rods of felspars have begun to crystallize from a yellowish glass, causing a concentration of the magnetite grains at their ends. A small amount of olivine is present (Pl. 18, fig. 2).

9681. STREAM BEYOND TA-WANG-MAO.

In this group must also be placed an interesting rock from a stream beyond Ta-wang-miao (Plate 18, fig. 3). It is an augite andesite containing chlorite, which plays the part of a glassy base.

The rock has a greenish mottled appearance with white spots due to kaolinised felspars, which are chiefly labradorite; they are much corroded by the groundmass so that the original crystal outlines have disappeared; they contain inclusions of magnetite, chlorite and small augites. These inclusions frequently arrange themselves along the albite lamellae and the whole crystal presents an appearance of schillerisation. No colourless glass inclusions occur in the felspars. The augite phenocrysts are light brown in colour, their outlines are tolerably well preserved and basal sections are fairly common. One good example of a twin on the plane (100) occurs. The peculiar shape of the crystal is due to the lengthening of the prism faces and the consequent shortening of the pinacoids. The augite phenocrysts sometimes show re-entrant angles due to corrosion, and contain inclusions of plagioclase,—this fact together with the occurrence of glomero-porphyritic aggregates of augite and felspar proves that these two minerals crystallized out at approximately the same time.

True glassy base does not occur in the rock and its place seems to be taken by chlorite. The groundmass consists of yellowish brown augite grains of a somewhat darker colour than the phenocrysts, felspar laths, magnetite and chlorite. The magnetite is comparatively rare and occurs in scattered crystals rather than as small grains as in the other andesites. The augite grains are sometimes enclosed in the chlorite and their borders are quite sharp, so that it would seem probable that a decomposition from augite into chlorite has taken place. The chlorite occurs in exactly the same manner as groundmass glass in an ordinary andesite, filling up the spaces between the crystals and occurring as large round amygdules; it is slightly pleochroic, and gives blue double refraction colours; it is apparently composed of a large number of small spherulitic grains each of which shows a black cross between crossed nicols; it encloses rounded grains of sphene and chalcedony; the latter seems to be the last product of alteration, the sphene is also a product of alteration of the original glass since it does not occur as inclusions in the other constituents of the slide.

Olivine-augite andesites. The olivine bearing rocks in the massive andesite group have been divided into olivine-augite andesites and olivine basalts. The division is largely a matter of convenience, as the subdivisions pass into each other and no strict line can be drawn separating them. Their chief distinctions are as follows:—

The olivine andesites contain less magnetite, less augite and more felspar and generally less olivine; and the occurrence of large porphyritic crystals typically developed in andesites is well seen; moreover, the typically developed ground mass of the andesites is hyalopilitic.

The olivine basalts of the group are much lighter coloured than those of group I, owing to the smaller content of magnetite; most of them would be classified in the field as andesites, but a closer inspection under the microscope leads to their classification as basalts, owing to the evenness of texture and the large content of olivine. Both series contain about 54 per cent. silica but high silica percentage is a characteristic of all the rocks of this province.

26·162; 9670. BELOW COMMISSIONER'S HOUSE, TÊNG-YÜEH.
S.G.=2·48.

Light-grey scoriaceous lava crowded with small bubble holes. A few black porphyritic crystals of augite are visible. Under the microscope it is seen to contain phenocrysts of labradorite and andesine much corroded by the groundmass, with smaller phenocrysts of brown augite and olivine. The felspars contain inclusions of magnetite, zircon and yellow glass and show zoning and albite twinning to a large extent; they occur in glomeroporphyritic growths with the augite, which is generally schillerised and much fractured. The olivine crystals are small and corroded by the groundmass, they often show a red border which has been attributed to weathering, and by some authors to magmatic resorption taking place while the eruption of the lava was in progress. In some cases the secondary mineral developed from the olivine is lamellar and similar to iddingsite. The groundmass contains a large amount of yellowish white glass, felspar laths, yellowish augite grains and magnetite, with an approach to hyalopilitic structure typical of the andesites. The rock contains 54·3% SiO_2.

21·689; 9688. ½ MILE SOUTH OF THE BRITISH CONSULATE, TÊNG-YÜEH.

This is another rock of the same type; it is a light-grey, strong, pumicious lava with many, irregular, ramifying bubble holes. The felspar phenocrysts and aggregates are worthy of mention.

They are frequently very large and strongly zoned containing inclusions of yellowish glass and augite; the former occur particularly around and near the edges of the crystal where they form a network: some of the crystals are so corroded and penetrated by the groundmass that a portion of the crystal is isolated though optically continuous with the rest of the felspar. Large aggregates of six or seven crystals of felspar occur, their arrangement is quite irregular and they contain many inclusions. Several crystals seem to have commenced to form at the same time and in this way have grown together, enclosed a little augite and impeded each other's growth, so that where several crystals meet, no crystallographic edge is developed. The effect is best seen between crossed nicols. The conditions influencing the formation of these felspar aggregates or segregations are difficult to imagine, they are generally developed in plutonic rocks and in dykes, and their formation is probably associated in some way with pressure.

The olivines show better rims containing red iron oxide than the last example, and in some cases a third rim of secondary olivine is developed round the extreme edge of the crystal. Better examples of this structure are met with in an olivine basalt from the road south of the waterfall at Têng-yüeh, a description of which is found below. Some of the olivines have assumed a most peculiar form owing to corrosion; one crystal was shaped like a double anchor.

26·158; 9674. 1 MILE BELOW MONG-LIEN. S.G.=2·625.

Olivine basalts (light-coloured).

Light-grey rock with small pyroxene and felspar and larger olivine crystals in a fine crystalline base. The olivine is the only mineral in the slide forming large porphyritic crystals; most sections are parallel to the prism axis but some basal sections show good pinacoidal cleavages. It is light-yellow in colour with a red border due to weathering but shows no evidence of decomposition into serpentine. The main body of the rock is composed of a felted mass of oligoclase and andesine laths with probably some labradorite, often showing a tendency to radiate structure with small, brown augite and olivine crystals between them; magnetite occurs only in a small quantity. There is a very small amount of glass in the rock which on account of the large amount of olivine present is placed with the olivine basalts. Its silica percentage is rather high, (54·93 %), and the proportion of felspar laths to augite grains is also high for a basalt, but on account of the absence of large porphyritic felspars characteristic of the andesites of this area and the fact that the high percentage of the silica may be attributed to the relative rarity of magnetite, the rock must be classified as a light-coloured olivine basalt.

Other similar rocks occur containing vesicles and long rod-like crystals of magnetite.

9687. SOUTH OF WATERFALL, TÊNG-YÜEH.

This is one of the most interesting rocks of the district. It is a light-coloured rock with phenocrysts of plagioclase and olivine and a groundmass composed of felspar laths, augite grains in great numbers, and magnetite.

The felspars are sometimes quite large and curved owing to strain, contain inclusions of glass, magnetite and augite; they are quite fresh but often corroded. In some cases a felspathic segregation has taken place and aggregates of seven or eight crystals have grown together enclosing augite and impeding each other's development; these are chiefly labradorite and andesine. The groundmass is composed of many light-brown augite grains, felspar laths, with magnetite in small amounts and olivine. Glass is absent. The chief characteristic is the occurrence of incomplete felspars with indented edges like a fern, these being filled up with augite. The magnetite has crystallised out in rods and fern-like forms, and is evenly distributed throughout the rock. These properties are characteristic of many true basalt dykes. The chief interest of the rock lies in the abundance of olivine phenocrysts with resorption rims surrounded by an additional rim of secondary olivine. (Pl. 19, fig. 1.) The olivine crystals are corroded much more than the felspar, the groundmass having penetrated to the centres of the crystals. They show good pinacoidal cleavage and extinction is generally about 5° from straight. The majority of the crystals are composed of three zones:—

1. A large internal area often clear and undecomposed, and traversed by fracture and cleavage cracks, sometimes slightly yellowish or greenish and containing inclusions of the groundmass and magnetite.

2. This is surrounded by a dark-red, nearly opaque zone containing a large amount of ferric oxide, and extinguishes at a slightly larger angle than the central area; on the inside edge there are rays and irregular patches of a light-yellow colour proceeding into olivine; they presumably contain much less iron oxide.

3. Finally, in contact with the groundmass of the rock we have a very narrow rim of a light-yellow substance which is optically continuous with the internal area and gives the same double refraction colours as olivine, it was proved to be secondary olivine; this determination was confirmed by gradually closing the diaphragm and comparing the surfaces of the two crystals; the refractive indices were found to be the same. It may be mentioned that many of the cracks affecting the olivine are not continued into the external rim of secondary olivine and that the other zones follow the indentations of the original olivine crystal. The red zone coloured by ferric oxide fills the whole crystal and since it follows the irregular shape of the olivine due to the corrosion of the magma, it must be later than this. It is interesting to note that although the resorption rim generally occurs where the olivine comes in contact with a felspar crystal, yet the external rim of secondary olivine is absent at the point of contact with the felspar, although present on the other edge of the crystal (see Plate 19, fig. 1 at "a"). It is therefore not a reaction rim, but due to a later withdrawal of olivine from the material of the groundmass while still in a viscous state. This also proves that the resorption rim is of much earlier formation. It was probably formed while the olivine

crystals which were formed under plutonic conditions, were floating in the magma, and may be due to reduction of pressure as suggested by Washington for the rims on hornblende and biotite in andesites.[1]

It was after this period that the felspar crystal was pressed into contact with the olivine and thus prevented the formation of the rim of secondary olivine on the outside, *i.e.*, the resorption rim is probably due to reduction in pressure on eruption, whereas the secondary olivine rim is due to deposition of a second generation of olivine from the magma, a part of which formed small crystals in the groundmass.

This rock is very similar to that from a point half a mile south of the British Consulate at Têng-yüeh, and may be the same, thus illustrating the difficulty of separating these olivine-bearing rocks into andesites and basalts.

26·155; 9695. HEAD OF THE DIVIDE ABOVE HAI-KOU LAKE, TÊNG-YÜEH. S.G.=2·46.

Amphibole Andesites.

This is a light grey rock with glassy felspars, biotite and hornblende in a finely crystalline base. The texture of the groundmass is hyalopilitic, the felspar microliths being very small and associated with a little magnetite and glass which occurs in rounded patches. Crystals of apatite are common. a small amount of nepheline also occurs in the groundmass but hornblende seems to be absent.

Felspars are the dominating porphyritic constituent, they are chiefly andesine and labradorite with oligoclase. They are quite undecomposed but are invaded by ramifying offshoots of clear colourless glass and also zoned with glass; the inclusions consist of magnetite and glass. In some cases corrosion has produced a step-like structure on the terminal planes of the felspar. Pericline twins are sometimes seen.

The ferromagnesian constituents are chiefly biotite, hornblende and a small amount of enstatite with augite. The mica and hornblende are both very much altered, the whole crystal is

[1] H. S. Washington "Magmatic alteration of Hornblende and Biotite." *Journ. Geol.*, Vol. IV (1896), p. 257.

frequently obscured by a mass of opaque matter consisting of magnetite and augite. The hornblende is a light-greenish-brown colour, slightly pleochroic and in the majority of cases has been corroded, and is irregular in shape with a resorption border. The biotite is dark brown and strongly pleochroic. The dark resorption bands (Pl. 18, fig. 4) are irregular in width, and under high powers are seen to consist of radiating prisms of augite, partly obscured by an irregular mass of magnetite grains; short rays of this resorbed border material penetrate from the hornblende into the groundmass, with glass or nearly amorphous felspar matter filling in the interspaces. In most instances the hornblende or biotite with the resorption rim retains its shape, but cases occur where corrosion has gone on to a large extent and formed re-entrant angles admitting the groundmass.

These rims are supposed to be due to the instability of biotite and hornblende under conditions of high temperature and reduced pressure.[1]

The crystals have originally been formed from the magma under plutonic conditions but as it was gradually rising in the earth's crust preparatory to eruption,—the temperature being maintained high and the pressure reduced,—the complex molecules of hornblende and biotite broke down into augite and magnetite with sometimes a little felspar. This is no doubt true to a great extent, but as pointed out, evidence of magmatic corrosion exists, so that the magma must have had some chemical action on the crystals of hornblende and biotite. In many cases the whole crystal is obscured by magnetite to such an extent that it seems impossible for it all to have come from the conversion of hornblende into augite and magnetite; some of it has probably been absorbed from the groundmass, just as during the corrosion of a felspar, magnetite is frequently deposited. The reaction does not seem to be so simple as has been imagined and further investigation is necessary; microchemical tests with hydrochloric acid are of value in removing a large amount of magnetite and exposing the minerals of the rim to greater advantage.

Resorption rims occur in other specimens of the nepheline-bearing amphibole andesites. Washington was of the opinion that the resorption rims depended on the texture of the rock and were rare in fine-grained rocks owing to the rapid cooling; but

[1] H. S. Washington, *loc. cit.*, p. 257.

this explanation does not apply to the rocks from Yünnan, since out of several rocks with the same texture and general appearance, some have resorption rims and others not. The percentage of silica in this rock is 66·86 %.

26·152; 9677. TOP OF THE SHWELI-TÊNG-YÜEH DIVIDE. S.G.=2·47.

A somewhat similar rock with sufficient differences to warrant a separate description overlies the crystalline rocks of the Shweli-Têng-yüeh divide. It is a bluish-grey massive rock with a few porphyritic crystals of biotite, amphibole and glassy felspars in a finely crystalline base. Round the edges the rock is decomposing into a light-grey mass. Under the microscope the porphyritic constituents prove to be felspar, hornblende, biotite, enstatite, augite and nepheline. The felspars are oligoclase with andesine and labradorite and are much fractured, strained and corroded, as described in some of the other rocks. A characteristic of this rock as of others from this area, is the occurrence of a large number of cases in which two crystals of plagioclase have grown together in such a way that the traces of the planes (010) are at right angles, thus producing knee-shaped aggregates with a small amount of glass included along the junction of the two crystals. There are also several examples of knee-shaped twins of felspar, in which Carlsbad, Baveno, and albite types of twinning are found in the same combination; this will be discussed later. Glomero-porphyritic growths of felspar and pyroxene occur in this slide. The hornblende is a dark brown variety with a pleochroism of ordinary hornblende and not the alkali variety; it contains inclusions of colourless glass and magnetite and has no resorption borders. This is remarkable since a very similar rock, No. 26·155, shows many examples. Biotite is not very common but occurs in dark brown sections which are nearly opaque when the light vibrates parallel to the vertical axis; sections parallel to the basal cleavage are rare. The groundmass is hyalopilitic, containing felspar laths, mostly oligoclase, with biotite, a small amount of pyroxene, and a considerable quantity of colourless glass. The felspar microlites form a well marked flow structure round the porphyritic crystals. This rock is also interesting from the occurrence in it of nepheline; one large hexagonal crystal, quite fresh and unaltered was observed, and smaller ones were detected on treating the slide with hydrochloric acid and colouring with methylene blue; the nepheline in the groundmass is the squarish or irregular forms and is rather rare, but is sufficient, I think, to place the rock in the alkali series. (Pl. 19, Fig. 2.) Enstatite is found in long, light-brown, prismatic sections with characteristic sea-green and reddish-brown pleochroism, its extinction is never quite straight, angles of five degrees being common. Enstatite is next in importance to hornblende as a porphyritic constituent; augite occurs rarely in brown longitudinal sections. The rock is therefore a nepheline-bearing enstatite amphibole andesite.

The combination of Carlsbad, Baveno, and albite twinning.

The most characteristic twin of this group with the above types of twinning in one combination is represented in Pl. 19, Fig. 3. It consists of four parts—x, y, n and m; x and y are Carlsbad twins, CR being the trace of the twin plane; n and m are twinned in the same way along PQ. In each of these four parts albite twinning can be detected, the lamellae being parallel to IB and KB respectively. These lines are therefore the traces of (010) the composition plane of the albite twin. The above parts of the combination are found to extinguish at different angles between crossed nicols; the angles are as follows:—

x	19°	measured from AN.
y	10°	
n	34°	measured from AD.
m	21°	

The sections are thus cut obliquely and not perpendicular to (010) and there is no apparent relationship between the extinction angles of the different parts; different parts of the same individual extinguish at different angles according to the part of the crystal which is considered; the above angles were all measured on parts of the crystal nearest the line AB. Angular measurements were made to determine whether AB is the trace of (010). $\angle$DAB=138° (42°) and $\angle$ NAD =94°. From the measurements given in Dana's System of Mineralogy we find that (010) $\wedge$ (021) =43° 33′ which, within the limits of error, is equal to $\angle$DAB. AB is thus the trace of the Baveno twin plane (021), and we have associated in one combination the Carlsbad, Baveno and albite types of twinning. The trace of the twin plane (021) is irregular as shown and has a slightly yellowish appearance due to the inclusion of a small amount of glass along it.

The second example is shown in Fig. 4. The parts of the crystal which we must consider separately are a, x, and y. They all show traces of albite lamellae and one prominent lamella ZB can be seen projecting beyond the edge DN. If we first consider x and y as one individual, we see that "a" is twinned with them on the Carlsbad plan along AB, but x and y are twinned along YZ, which in this case is a quite regular and well defined line. As before the edge XY is the trace of (010), being parallel to the albite lamellae. The extinction angles measured in an anticlockwise direction from AB are y=22°, x=42°, and a=54°. Now $\angle$ XYZ=140° (40°) and $\angle$XYM=90°, but XY is (010), and (010) $\wedge$(021)=43° 33′, so that YZ is the trace of the dome (021), and x and y are twinned on the plane (021); we thus have the same three types of twinning occurring together. It will be noticed that the crystals are all well zoned; the lines of inclusions in Plate 19, fig. 2, follow the outline of the crystal, turning in a new direction at right angles when they reach YZ.

The above-mentioned felspars are labradorite and the explanation given by the twinning is put forward with a considerable amount of hesitation because of the fact that the crystals are only seen under the microscope, and, in addition the sections are not perpendicular to (010) but are cut obliquely. The usual Baveno twin gives a square section but there seems to be no reason why the elongated forms represented in the above figures should not be possible. Whether the explanation is the correct one or not, the peculiar grouping of the several parts of the felspar crystals is worth recording.

26·156; 9676. QUARRY BELOW MAN LA.

This rock is similar to the preceding containing biotite and hornblende with resorption rims and rather more nepheline, distributed in longitudinal and irregular sections in the groundmass (Pl. 20, fig. 1). The sections are fairly large of about equal size with the medium-sized felspars; the nepheline is undecomposed but often cracked and the centre is frequently worn away in grinding. It sometimes contains a few gas and opaque inclusions but is generally quite clear. No perfectly hexagonal sections are seen but prismatic and basal cleavages are well developed. Most of this groundmass nepheline was stained with fuchsine-red and when tested gave a uniaxial figure in convergent light.

Many of the felspars are quite glassy and devoid of albite twinning, with the appearance of sanidine, but on testing sections parallel to (010), the extinction angles are all too large for sanidine. The rock is very fine-grained like the preceding.

In some cases it is doubtful whether to place a particular rock with the pyroxene andesites or with the amphibole andesites, since the proportion of the enstatite and amphibole vary considerably. Intermediate types occur similar to the rocks named pearlites by Iddings.[1]

Pyroxene Andesites.

Pyroxene andesites are not so numerous among the massive andesites as in the bedded group; rocks of this type seem to occur sparingly and often show a transition to the amphibole andesites.

9683. TWO MILES BELOW HAI-KOU.

This is a fine-grained, stony rock with enstatite as the predominating pyroxene; this mineral occurs in small, porphyritic crystals which are light-brown in colour and contain many inclusions of glass, magnetite, and gas bubbles. A crossed twin of enstatite was seen to have a rim of granular mineral round it, which was optically continuous with it and gave the same double refraction colours; it is apparently a rim of granular enstatite, whether it is secondary or not is difficult to determine. The felspars are the largest and most important porphyritic constituents; they are quite fresh and strongly zoned with glass and magnetite. The groundmass is glassy containing indeterminable, colourless microlites, frequently in radiating groups, with small specks of magnetite attached to them and colourless glass in the interspaces. Other constituents are light-brown augite grains and felspar laths, both of which occur in fairly large quantities. The augite is slightly darker in colour than the enstatite, and occurs rather as a constituent of the groundmass than as porphyritic crystals. The rock is thus probably a devitrified glass of the composition of enstatite andesite.

[1] Iddings, *Monogr. U. S. Geol. Surv.*, XX, p. 368.

26·153; 9685 QUARRY BELOW WATERFALL ON HO-SHUEN-SHAN.

Mottled, greyish-white, partly decomposed rock showing a few glassy felspars and biotite flakes; the groundmass is stony and clouded due to decomposition.

Under the microscope the groundmass is seen to be composed of white and greyish glass distributed in patches with short longitudinal sections of biotite, felspar laths and small magnetite grains. No flow structure is visible. The mica in the groundmass is frequently very irregular in shape with ragged edges and is strongly pleochroic. Long crystals of apatite occur with a well developed basal cleavage and containing inclusions of magnetite. The slide is opaque in parts owing to decomposition into an earthy grey amorphous substance. The felspars give small extinction angles and seem to be mostly oligoclase. Zoning and re-entrant angles due to corrosion are conspicuous in the larger felspars; two or three crystals have sometimes grown together and as a result of corrosion a very irregular outline has been produced; after the work of corrosion was complete zoning action commenced, and as a result a most irregular band of glass and magnetite now follows the outline of the crystal within a short distance. The interior of the felspars is ramified with strings of colourless glass. The larger felspars are mostly oligoclase and albite with a few andesines. The other porphyritic constituents are biotite, enstatite and augite; the enstatite is found in the usual light-brown, pleochroic, longitudinal sections and is more numerous than the other ferro-magnesian constituents. The augite is light-green in colour and contains inclusions chiefly of magnetite and glass; hornblende occurs but is not an important constituent. The rock is a pyroxene andesite containing biotite, and is an intermediate type between the pyroxene andesites and the mica-hornblende andesites.

26·163; 9675. JUST OUTSIDE MAN-CHIN. S.G.=2·62.

The andesite glasses.

This is a black compact rock with a dull glossy lustre, which on a freshly fractured surface has a speckled sheen, due to the occurrence of numerous minute crystals of felspar arranged in flow lines. It contains a few porphyritic felspar and yellow pyroxene crystals, arranged in flow lines which weather out and leave hollow spaces; a few secondary grains of quartz are also visible. The whole rock is remarkably fresh and the only change which affected it, is a slight amount of devitrification. It contains 61·66% SiO_2. Under the microscope it is dark coloured, the groundmass consists of a network of felspar microlites curving round the phenocrysts in flow lines; magnetite grains collect at the end of the microlites, which are in a very elementary state of crystallisation, and the rest of the groundmass is a clear glass. Pyroxene occurs in sections parallel to the prism axis, exhibiting the pleochroism of enstatite, with a straight extinction. The crystals are light brown in colour and contain inclusions of glass, magnetite and liquid inclusions with a bubble. The enstatite sometimes occurs in aggregates of several small crystals round a larger one. Augite is found in stout crystals, some of which are nearly round, of a slightly darker colour than the rhombic pyroxene; they are easily distinguished by cleavage, and double refraction colours. Twins of augite are fairly common; felspar phenocrysts are rare, and consist of andesine and labradorite, all have ragged edges owing to magmatic corrosion; one quite fresh crystal of felspar shows a series of star-pointed rays of glass and magnetite grains, directed from the edge of the crystal into the felspar material with fresh felspar between them. Under high powers the section parallel to the surface of the flow show alternating light and dark bands more or less parallel to the longer axes of the phenocrysts; a similar structure has been described in a tachylyte from the north of England.[1]

The dark bands are slightly coarser in texture than the lighter bands, and owe their colour to the abundance of an irregularly distributed opaque substance.

26·157; 9680. VILLAGE OF HSIANG-SHUI-KOU. S.G.=2·43.

Dark grey mottled rock with a few felspar phenocrysts in a glassy ba se, which shows a well developed flow structure; the concentric layers of glass in each spherule stand out conspicuously owing to the weathering away of material round the edges; the average size of the spherules is about one mm. Under the microscope the perlitic structure is beautifully shown (Pl. 20, Fig. 2), and a greenish decomposition product is developed at the junctions of the individuals of glass. On closer examination the groundmass is seen to be composed of a colourless glassy base with radiating felspar microlites

[1] Miss M. K. Heslop and R. C. Burton. "The Tachylyte of the Cleveland Dyke." *Geol. Mag.*, Feb. 1912.

and magnetite grains, which are chiefly developed in or near the microlites, being much rarer in the colourless glass. The porphyritic crystals consist of felspar, augite and enstatite, the latter being the dominating pyroxene. Glomero-porphyritic aggregates of felspar and pyroxene occur, in which the pyroxene is usually curved and fractured Pl. (20, fig. 3). The felspars are quite fresh and consist mostly of labradorite often greatly corroded by a yellowish brown glass, developed particularly between the albite lamellæ; the inclusions consist of long prismatic negative crystals, apatite, gas inclusions and magnetite. The enstatite is light-brown in colour and shows good pinacoidal cleavage, while the augite is light-green to brown, contains many inclusions, is non-pleochroic, and occurs in rounded sections. The rock is a pyroxene andesite glass with perlitic structure, and contains 65·96% SiO_2.

3. Bedded Andesites.

The rocks of this group are probably the oldest volcanic rocks dealt with in this paper. They are bedded rocks with an ashy appearance. The planes of separation are sometimes one inch apart, but vary considerably. In some outcrops they are distinctly folded and contorted by pressure, but whether there was a great difference in time between their eruption and that of the massive andesites, is rather doubtful from the field evidence. Judging from their comparative freshness under the microscope the difference is small and the rocks are most probably Tertiary. They are chiefly fine-grained pyroxene andesites of a rather acid type.

26·159; 9679. HSIANG-SHUI-KOU, TNG-YÜEH DISTRICT. S.G.= 2·43.

This rock consisted of numerous kaolinised felspars in a slaty-grey groundmass with conchoidal fracture and showing no crystalline structure. Under the microscope the porphyritic felspars are large and comparatively fresh, often occurring in strongly zoned groups of two or three. Some crystals are filled with yellowish glass, which has first proceeded along the cleavages and twin lamellæ, and then by a series of cracks has cut right through the section so that only a small amount of felspathic matter is visible. Inclusions of magnetite are common. The felspars are chiefly andesine, and occur in glomero-porphyritic aggregates with enstatite and augite (Pl. 20, fig. 4). Some of these groups are traversed by cracks along which a yellow glass has intruded into their midst. This glass has now devitrified and forms a series of fibres, parallel or perpendicular to the fissure along which it has intruded. The augite is light-brown, slightly pleochroic, and often fractured; it contains inclusions of magnetite and glass. Rhombic pyroxene is slightly commoner than the augite, sometimes has the appearance of schillerisation, is often invaded by glass and curved by pressure (Pl. 20, fig. 3) and has frequently crystallised with felspar. Magnetite crystals are not common. The groundmass is nearly opaque and of a dirty-brown colour; under high powers the brown substance is resolved into patches of opacite and innumerable small magnetite grains with a few sections of apatite; the groundmass is mainly glassy, but in a few cases skeleton augites and microlites of felspar can be detected. No amphibole occurs in this rock, which is therefore a glassy pyroxene andesite.

21·693; 9692. 100 YARDS N. E. OF HSIAO-HOTI-HO.

Bluish bedded rock with a thin covering of red iron oxide and dendritic markings on the division planes. In a section parallel to the bedding we see porphyritic crystals of plagioclase, augite and enstatite—sometimes intergrown. As in most of the other rocks the plagioclase is ramified by glass inclusions, the enstatite is more plentiful and lighter-coloured than the augite. The groundmass is dark-coloured and is divided into alternate light and dark bands, which show a conspicuous flow structure as they curve round the porphyritic crystals; flow structure is also evident from the trend of the elementary magnetite crystals. The rest of the groundmass is colourless glass with a few belonites and magnetite grains developed.

The rock is a glassy pyroxene andesite.

21·696; 9694. SOUTH OF YAO-WU-SHAN.

This rock more nearly approaches the rocks named pearlites by Iddings than any of the others of this group; it contains biotite and hornblende in addition to the enstatite and augite. The groundmass between crossed nicols is practically opaque and is crowded with a felted mass of elementary rod-like crystals. Magmatic corrosion has proceeded further than in most of the other rocks; one augite crystal has quite a sharp, well defined edge except at one point, but a large part of the centre of the crystal has been invaded by glass which has partly decomposed into hæmatite obliterating the augite. No resorption borders are visible round the biotite and hornblende. At one point a crack filled with colourless glass containing a little magnetite completely crosses the slide, swelling out and enveloping a felspar crystal; it is noticeable that where the colourless glass corrodes a felspar crystal, a yellowish fibrous substance is produced, the exact nature of which is doubtful.

Conclusion.

It will be interesting to trace as far as possible the order of eruption of the successive lava-flows in the Têng-yüeh area; as we have seen, the lavas of group 3 are mostly pyroxene andesites, containing in some cases a certain amount of hornblende; then followed amphibole andesites and augite andesites with light-coloured olivine basalts and pyroxene andesites, and lastly the series of black olivine basalts of Ho-shuen-shan, Tay-in-shan, and the Kung-po volcanoes were erupted. Tabularly arranged the order of eruption is as follows:—

1. Pyroxene andesites.
2. Hornblende andesites, augite and pyroxene andesites, with olivine-augite andesites and olivine basalts.
3. Olivine basalts.

It will be noticed that the volcanoes of the Têng-yüeh district lie not very far from the line which joins Barren Island and Narcondam with Mount Popa, in Central Burma, and Loi-han-hun in the Shan States, where La Touche discovered Tertiary basalts. This line forms the northerly continuation of the Sunda volcanic chain running through Java and Sumatra. The mere geographical alignment is supported by a petrological examination of the lavas from the several areas:—

Java and Sumatra—chiefly andesites with some leucite rocks;
Barren Island—chiefly olivine dolerites;
Narcondam Island—hornblende andesites with a few ashes;
Mount Popa—augite andesites;
Loi-han-hun—olivine basalts;
Têng-yüeh area—andesites and olivine basalts.

In addition all the eruptions are recent or of late Tertiary age and the order of eruption seems to have been the same as in the

Têng-yüeh area, *viz.* :—hornblende andesites were followed by olivine basalts, since the andesites of Narcondam Island are older than the olivine dolerites of Barren Island.

It is therefore probable that the whole of this series of volcanoes from the Sunda chain to Têng-yüeh is on one line of volcanic activity. We have mentioned the occurrence of nepheline-bearing rocks in Yünnan; rocks of Atlantic type have not been previously reported from Yünnan, but Leclère [1] discovered a nepheline syenite occurring as dykes in the Archaean of Ssuchuan. Most of the rocks we have described are of a pronounced Pacific type, and the occurrence in them of alkaline rocks may be due to one of two causes :—

(1) they may indicate the occurrence of the boundary between the Pacific and Atlantic provinces in Yünnan ;

(2) they may be sporadic, indicating a slight intermingling of Atlantic with Pacific types, as in Java.

The line of separation between the Pacific and Atlantic provinces drawn by Harker [2] ends near the island of Sumatra ; if therefore the classification is of value as indicating provinces based on geological as well as petrological factors, we must evidently continue the boundary along the volcanic line from Sumatra to the Têng-yüeh area ; this would place India in the Altantic province, although we know from a study of the late Cretaceous and Tertiary rocks that India is characterised by the occurrence of a vast area of sub-alkaline lavas—the Deccan trap. Alkaline rocks have only been recorded from one or two places, *viz.*, monchiquite and nepheline syenite in Kathiawar [3] and tingauite near Sarnu in Rajputana.[4] These occurrences are doubtless sporadic and do not interfere with the contrary view that India is part of the Pacific Province which is supported by the fact that sub-alkaline rocks are found in Persia, Baluchistan and Tibet. It is thus probable that the complexity of the tectonic relations of the Indian Empire render a strict application of the principle of division of the rocks into two distinct provinces impossible.

[1] *Bull. de l'Académie des Sciences*, 29-1-1900 and *Annales des Mines*, ser. 9, Vol. XX (1901), p. 302.

[2] Natural History of Igneous Rocks, p. 97.

[3] J. W. Evans, *Quart. Jour. Geol. Soc.*, Vol. LVII (1901).

[4] T. D. LaTouche, *Mem., Geol. Surv., Ind.*, Vol. XXXV, p. 90.

EXPLANATION OF PLATES.

PLATE 18.—Figure	1.	Newer basalt lava.	× 19.
„	2.	Augite andesite with olivine.	× 19.
„	3.	Augite andesite with chlorite.	× 19.
„	4.	Amphibole andesite showing hornblende.	× 19.
PLATE 19.—Figure	1.	Olivine basalt (light coloured).	× 32.
„	2.	Amphibole andesite with nepheline.	× 19.
„	3.	Felspar in amphibole andesite.	× 64.
„	4.	Felspar showing Carlsbad and other twinning.	× 64.
PLATE 20.—Figure	1.	Amphibole andesite with nepheline.	× 19.
„	2.	Andesite glass with perlitic structure.	× 32.
„	3.	Pyroxene andesite.	× 32.
„	4.	Glomero-porphyritic aggregate of felspar, etc.	× 32.

THE KIRANA AND OTHER HILLS IN THE JECH AND RECHNA DOABS. BY A. M. HERON, *Assistant Superintendent, Geological Survey of India.* (With Plates 21 and 22.)

I. Introduction.

Previous observer.

Until my visit at the end of 1909, these isolated hills had not been examined by any geologist, save for a reconnaissance, a day's stay only, by Dr. Fleming in 1852.

The account given in the "Manual of the Geology of India" (p. 72) is taken from his description.[1]

Situation.

The hills rise from the level and, but for recent irrigation, arid expanse of the Punjab alluvium in four separate groups at Kirana (31° 58', 72° 45'), Chiniot (31° 43', 73° 2'), Sangla (31° 43', 73° 25') and Shahkot (31° 34', 73° 32').

The first mentioned is between the Jhelum and the Chenab rivers (the Jech or Chaj Doab), the Chenab flows through the second group and the third and fourth lie between the Chenab and the Ravi (the Rechna Doab).

They thus extend in a direction from north-west to south-east over some sixty miles.

Of these, the Kirana Hills are by far the most important; there is a diminution in the extent and the height of the outcrops as we pass to the south-east.

Topography.

Though only forty miles distant from the Salt Range, the rocks are totally different from any occurring there and approximate in character more to those of the Aravalli Hills, the nearest point of which is 260 miles to the south-east.

Apart from the isolation of their situation and the steepness with which they rise from the alluvium, they present a remarkable appearance in their bareness of vegetation and the sharpness of their peaks. Though the hill masses are elongated in the direction of the strike, they are lines of shattered, serrate summits rather than ridges.

Another feature, specially noticeable in the Kirana group, is the blackness of the hills as seen from a short distance away. The

[1] *Jour. As Soc., Bengal*, XXII, p. 444.

individual rocks are not particularly dark when freshly broken, but all long-exposed surfaces are coated with a thin, black, shining film of iron oxide, drawn up in aqueous solution through interstices by the sun's heat, and which the scanty rainfall is inefficaceous in removing. This gives a great similarity in appearance to the exposures, aided by the close and splintery jointing of all the beds, resulting in a uniformly rugged and irregular aspect in which differences of stratification tend to be obscured.

Weathering.

Below the hard crust the rocks are rotten and break easily under the hammer into earthy and friable fragments. They are copiously impregnated with hæmatite.

In spite of the high inclinations at which the strata lie, no signs of schistosity were seen, even the slates are barely cleaved.

The metamorphism has been chemical and not dynamic; it has been caused by chemical rearrangements among the minerals of the rocks more than by heat and pressure developed in folding.

Kirana Hill.

The highest summit is that of Kirana, which gives its name to the group, 1,662 feet above sea-level, or 1,050 feet above the level of the plain. The top of the hill is the site of a tomb and a large settlement of *sadhus* and is a popular place of pilgrimage, its distinguishing peculiarity being that every visitor is presented with something to eat.

Sangla.

Sangla is identified with the Sangala visited by Alexander the Great. The expanse of brick ruins is a marked contrast to the modern town, a busy market centre of a thriving canal colony, suggesting the mushroom cities of the Far West more than the slowly moving East.

II. Description—Kirana Hills.

Strike.

These comprise a large number of very irregularly shaped rock masses, mostly elongated in a direction N.W.-S. E., coinciding with the strike. Dr. Fleming gives the strike as N.E.-S. W., but this is so only in the north-east arm of Kirana Hill, which, with part of Chinelwala Hill, would appear to be the vestige of one limb of an anticline, the other limb including the remainder of the hills in this group.

Dip.

Dips are high and variable in amount, ranging from 40° to verticality, and, with the exceptions just indicated, are to the south-west. Sections are clear, but owing to the separation of the hills from one another by spaces of alluvium, are partial and discontinuous. Throughout the hills the predominant rocks are hardened shales or slates and rather argillaceous quartzites, coarse and fine.

Shales and slates. The shales occur chiefly north-east, and the quartzites south-west, of a line passing midway through the hills; the two zones are not sharply differentiated, but are still broadly separable.

As a whole the rocks are thin-bedded and, as one passes across the strike, are seen to vary constantly almost every yard.

The shales (23·9, 23·15; 7564, 7570) are usually green or grey, much impregnated with ferruginous matter along the bedding and the numerous joints.

Quartzites. The quartzites are harsh in texture, and grey, purplish or reddish in colour. They also bear much iron disseminated, and segregated near cracks. (23·13, 23·21; 7568, 7576.)

Tuffs. From the angularity of the constituent grains and absence of bedding in some of the types which resemble quartzites in hand specimens, it is highly probable that some of them are altered tuffs. This is particularly so in Ghawala Hill. (23·6, 23·11, 23·33-4; 7561, 7566, 7588-9.)

Igneous rocks. Besides shales and quartzites there is a great development of thin beds of igneous rock, both acid and basic. In the field these, particularly the acid types, are with difficulty distinguishable from the quartzites, and even under the microscope the structure can only now and then be made out amid the copious secondary products into which the constituent minerals have weathered.

Discontinuity of outcrops and steepness of dip prevent individual beds from being followed far along the strike or dip, but there is every reason to believe that the acid rocks are effusive. In the case of the basic bands, two instances of inferred intrusion were seen, but in general the basic bands also lie in parallelism with the rocks above and below. On the accompanying map I have indicated the occurrences of basic rocks and also some of the more distinct beds of rhyolites and tuffs. There are probably many more (rhyolites and tuffs) unmapped, as I often found it impossible to distinguish between ordinary quartzites, tuffs and acid eruptives without preparing and examining a large number of microscope sections *pari passu* with my field work. This I had not the opportunity of doing at the time.

Basic igneous rocks.

The basic rocks are usually green or reddish brown, taking their colour from chlorite or hæmatite, whichever predominates, and they vary greatly in their texture. (23·7, 23·8, 23·10, 23·12, 23·16, 23·18, 23·28; 7562, 7563, 7565, 7567, 7571, 7573, 7583.)

Under the microscope the original structure is often difficult to decipher, but in certain sections the outlines of plagioclase felspars and irregular plates of augite can be seen, the latter sometimes enclosing the felspars ophitically. The felspars have been replaced by a fine mosaic of scaly quartz, muscovite and kaolin, the augite by chlorite, hæmatite and kaolin. Large crystals of leucoxene after ilmenite are present and magnetite in small grains. Calcite seems to have been largely removed and re-deposited in cracks and vesicles. Some of the specimens contain large crystals of quartz, presumably original phenocrysts. From the above considerations it is probable that these highly altered rocks represent basalts or andesites, dolerites and quartz dolerites.

Microscopic structure of tuffs, etc.

The sedimentary rocks vary from coarse grits to clay-slates. The grains are of quartz and magnetite imbedded in an argillaceous and ferruginous matrix.

In those which I consider to be tuffs, the grains are angular, in the normal aqueous rocks they are well rounded and the matrix is greater in amount than in the former. In one slide fragments of devitrified glass occur (7589). Tuffs and ordinary quartzites are not usually separable in the field. A curious point in connection with the tuffs is the number of small and very irregularly shaped cavities they contain, either empty, lined with hæmatite or filled with chalcedony. They doubtless represent the location of some mineral constituent which has been removed in solution.

Acid igneous rocks.

The acid effusives (23·17, 23·22, 23·23, 23·27; 7572, 7577, 7578, 7582) are classifiable as rhyolites. The phenocrysts are quartz and orthoclase, irregular and sub-angular in outline, the latter much kaolinised, and flocculent, brown, slightly pleochroic scales which are probably the remains of biotite. Green chlorite of similar origin also occurs. The cryptocrystalline base is usually vesicular and yellow in colour. Certain of the bands are devoid of phenocrysts, obsidian (23·14; 7569) and traces of spherulitic structure were seen.

Chiniot Hills.

These consist of a narrow broken ridge running west-north-west (the direction of the strike) across the course of the Chenab, which flows through the hills in a couple of picturesque gaps. They appear pale grey, red-mottled quartzites, alternating coarse and fine on the north side and slaty on the south, dipping at 40°-60° north-north-east. Under the microscope they are seen to be tuffs and volcanic agglomerates, consisting of angular fragments of quartz and devitrified glass in a dusty matrix. (23·33-4; 7588-9.)

Sangla Hills.

The Sangla Hills are composed of pale grey quartzites (23·36; 7591) similar to the above but finer in texture and more abundantly stained with red and purple ferruginous matter. They are thinly and regularly bedded and dip east and south-east at high angles, with copious and rectangular jointing.

Shahkot Hills.

The rock of the Shahkot Hills is still more ferruginous, fine grained and argillaceous. (23·37-8). The strata dip north-east at somewhat irregular angles, 50°-70°, and are more cleaved and altered than most of the other rocks. An isoclinal anticline runs midway through the group.

III. Comparison with rock-types from other areas.

Salt Range boulder bed.

It occurred to me that in the boulder-bed of the Salt Range, an assemblage of widely differing rock-types, accumulated probably in Talchir times by glacial agency, there might be some representatives of the rocks of the Kirana Hills.

With this end in view I examined the material available in the collections of the Geological Survey, including a set of typical samples of pebbles from the boulder-bed, collected by Middlemiss.[1] The majority of these are in no way similar to the Kirana rocks, but in a few cases noted below the resemblance, though not amounting

[1] *Rec. Geol. Surv. Ind.*, XXV, pt. 1, p. 29.

to identity, is enough to show that some of the rocks of the boulder-bed were in all probability derived from the area under consideration.

Boulder-bed.	Kirana.	
[illegible], 656[1]	[illegible], 7587; [illegible], 7587	devitrified rhyolites with quartz and felspar phenocrysts.
[illegible], 663	[illegible], 7589; [illegible], 7581	coarse-grained tuffs (?)

Malani and Tusham volcanoes.

With regard to the Malani rhyolites[2] and the felsites of Tusham,[3] there is a reasonable likelihood that the rocks of these three widely separated areas are identical in age. Though my specimens from the Kirana Hills are much more weathered than the large series collected by La Touche, yet the general type is the same. This also appears to be the case when tested by the description of the Tusham felsites by McMahon. The Kirana and Tusham rocks agree in the presence of small amounts of biotite, rare in the Malani types. In their field relations the Malani rocks are associated with non-volcanic sediments to a much less extent than are the Kirana effusives (and the Tusham felsites as far as can be judged from the small exposure). This would seem to indicate that, passing to the north, the results of volcanic activity have diminished and the flows dovetail into ordinary sediments. This is confirmed by the vastly greater thickness of the separate sheets in the south, in the Malani area. At Kirana and Tusham dips are higher than among the irregularly and moderately undulating strata of Malani.

Malani basic dykes.

The basic rocks of Kirana somewhat resemble the olivine dolerite dykes of Malani[4] except that olivine is not recognisable in my sections. Alteration has proceeded so far however that this is no proof of its initial absence.

[1] The first numbers refer to band specimens, the second to microscope sections in the Geological Survey collections.

[2] Blanford, *Rec. Geol. Surv. Ind.*, X, p. 10.
Oldham, *Rec. Geol. Surv. Ind.*, XIX, pt. 2, p. 124.
McMahon, *Rec. Geol. Surv. Ind.*, XIX, pt. 2, p. 161.
LaTouche, *Mem. Geol. Surv. Ind.*, XXXV, pt. 1.

[3] McMahon, *Rec. Geol. Surv. Ind.*, XVII, p. 108.

[4] *Mem. Geol. Surv. Ind.*, XXXV, pt. 1, pp. 25, 91.

Ajabgarh slates and quartzites.

The quartzites and slates of Kirana bear a general family resemblance to the Ajabgarhs of North-Eastern Rajputana, but when dealing with groups of altered sedimentaries in such widely separated areas, general resemblances are of little or no value in correlation, and it would be rash to base a statement of identity on evidence so imperfect. It is, however, probable that they belong to the Peninsular series rather than to the Extra Peninsular, and may be included in the Purana Group.

IV. Economic Chapter.

Iron.

According to Dr. Fleming[1] "The sandstone" (*i.e.* slate of Kirana Hill) "is traversed by numerous veins of white quartz containing masses of rich hæmatite iron ore, which do not seem to have attracted at all the attention of the natives as a source of iron, although it can be obtained in considerable quantity and ought to yield from seventy to eighty per cent. of metal. Filling small cracks in the sandstone some small specimens of pyrolusite or peroxide of manganese were obtained."

During my examination I saw very few of these quartz veins and I am unable to agree with Dr. Fleming's optimistic view. Though the large amount of iron present as films filling cracks and as interstitial material is one of the most noteworthy features of the hills, nowhere is it present in such purity or such amount as to justify exploitation. Here and there slag fragments are seen, from the former operations of those wandering *lohars* (blacksmiths) who tour the plains of Northern India, but in their work cheap imported iron has long supplanted that locally extracted from ores laboriously hand-picked from over considerable areas.

Pyrrhotite.

Pyrrhotite has been recorded[2] from Hundewali (Hoondiwala) Hill in masses up to one centimetre or more in diameter, scattered through compact grey-green quartzite. It is magnetic, brass-yellow in colour and contains neither nickel nor cobalt. There must be very little of the mineral, as Mr. Hayfield, who had been in charge of the North-Western

[1] *Jour. As. Soc. Beng.*, XXII, p. 446.
[2] *Rec. Geol. Surv. Ind.*, XXXI, pt. 3, p. 174.

Railway ballast quarries at Hundewali for two years, informed me that he had seen only one piece.

Railway ballast.

Hundewali and Sangla Hills are worked on a large scale by the North-Western Railway for ballast, and several of the others afford road metal.

EXPLANATION OF PLATES.

PLATE 21.—Sketch-map showing position of Kirana, Chiniot, Sangla and Shahkot. Scale 1" = 16 miles.

PLATE 22.—Geological map of the Kirana Hills. Scale 1" = 1 mile.

THE BANSWAL AEROLITE. BY J. COGGIN BROWN, M.SC., F.G.S., *Curator, Geological Survey of India.*

The object of this note is to put on record an account of the fall, and some petrological characters of a new Indian meteorite which fell in the village of Banswal, Mussoorie Sub-Division, Dehra Dun District, United Provinces, on the evening of January 12th, 1913.

Latterly it has been customary to postpone writing such accounts until several new Indian falls had accumulated, and then to describe them all together.[1]

It seems desirable however to alter this procedure, especially in view of the fact that duplicate specimens are often exchanged with museums and other institutions in foreign countries, and to record such details as may have come to light regarding the falls as soon as can be arranged afterwards.

On the 18th January 1913, the following paragraph appeared in the Calcutta "Statesman":

"A correspondent notes from Mussoorie:—On Sunday, the 12th instant, at about 6 P.M. a strange phenomenon occurred when suddenly the whole place became a blaze of light which was almost blinding to the eyes. On observers looking up for the cause they saw a large ball of fiery substance similar to a large cannon ball, travelling from north-west to south-east, throwing sparks. It suddenly burst with a fearful report, followed by two similar reports as if cannons were being fired. This was followed up with continual reports, as if a *feu-de-joie* was being fired, which lasted for fully ten seconds."

Judging from this account it appeared certain that the phenomena referred to were caused by the fall of a large meteorite, and it was surmised that fragments might have reached the earth in the neighbourhood of Dehra Dun and Mussoorie.

[1] "Notes on some Indian Aerolites." L. L. Fermor, A. R. S. M., B.Sc., F.G.S. *Records, Geol. Surv. Ind.*, Vol. XXXV, pp. 79—95.
"Notes on Indian Aerolites received since 1906." G. de P. Cotter, B.A., F.G.S. *Records, Geol. Surv. Ind.*, Vol. XLII, pp. 265—277.

An enquiry was therefore immediately instituted by the Geological Survey of India. and the Superintendent of Dehra Dun was asked to take steps to ascertain if any fragments of the meteorite had been received from the district under his charge. In India it is always essential to take early action in enquiries of this kind. for villagers who may have witnessed the fall usually regard it as a supernatural manifestation, and may even build a shrine over the fragments. which becoming objects of public veneration, are consequently lost to science.

We are indebted to the prompt action of the Superintendent of Dehra Dun for the recovery of a few fragments of the meteorite, which were obtained by the Sub-Divisional Officer of Mussoorie. The relevant features of this officer's report are given below.

On the 31st January he received information that Daya Ram, *mukhia* of Banswal, a hamlet of Chaman Sari, had found some pieces of the meteorite. and had them wrapped up in a cloth at his house.

The Sub-Divisional Officer started immediately for Banswal with the *mukhia*; on reaching the place which is about 10½ miles from Mussoorie. the circumstances of the fall were explained to him by the villager, who, after seeing the light and hearing the reports which accompanied it. stepped outside the door of his house, and while standing there heard something fall past his ear and strike a rock embedded in the ground 5 feet from the hut. The impact caused the fragment to break into small pieces, one of which struck a large wooden vessel about 2 feet high, used by the hill people for the transportation of oil and other liquids. Daya Ram then brought a light and commenced to look about, but as it had become too dark (about 6-30 P.M.). to see the fragments, he abandoned the search until next morning, when a mark was observed on the rock, and the small pieces of the meteorite were found scattered over a distance of 20 feet.

The Sub-Divisional Officer also reports that he witnessed the fall from a point near the Grand Central Hotel, Mussoorie, between 6 and 6-30 P.M. on Sunday, the 12th January 1913, "a fact not mentioned by the correspondent (in the 'Statesman'), is that there was a noise as of something large rushing through the air."

Further orders were circulated to the headmen of the villages around to make a second and more thorough investigation, but without any result. Chaman Sari village consists of more than a dozen hamlets at distances of about 2 miles from each other. The adjoining villages are also scattered, so that it is very probable that fragments fell without being observed, especially as it was nearly dark at the time and most of the inhabitants were in their houses.

The few small fragments received by the Geological Survey of India weigh only 13·77 gms. The bigger pieces average about 1·5 gms. and most of them show a black crust. The material is evidently part of the outer skin of a larger body.

The crust is of a dull black colour marked by small brighter patches. It is slightly scoriaceous and under a lens has a pitted surface; tiny cracks marked by reddish-brown limonitic stains can occasionally be seen. One small fragment of crust is pierced by a brighter irregular patch of fused nickel-iron.

The interior presents a fairly coherent, bluish-grey appearance, speckled with small patches of lighter colour. To the naked eye the chondritic structure is just visible, and under a lens it is seen that although most of the chondrules have smashed with the fracture, others protrude in spheroidal surfaces, especially in a narrow, somewhat whiter zone which lies immediately behind the black crust. Minute sparkling points of metallic matter are visible on the fractured surfaces, and the larger pieces of nickel-iron are marked by the rusting which they have undergone.

Under the microscope in ordinary light, a section presents a field of silicate and metallic grains in which the former constituents greatly outnumber the latter. There is some ferruginous staining localised mainly around the borders of the metallic grains, but sometimes spreading to the neighbouring silicates. Chondrules are abundant and make up a considerable proportion of the mass; for the most part they are of circular or oval outline, but a few are unsymmetrical. The oval ones are the largest and their long diameters average about 1·2 mm.; their edges are sharply set off from the groundmass. The spherical chondrules are smaller, more crowded together, and not so well distinguished from the groundmass. On an average they are about ·4 mm. in diameter.

The chondrules are chiefly composed of enstatite and olivine, either singly or in combination, the former mineral filling up the larger ones with radiating or parallel groups of needles and fibres, often intergrown with one another. Porphyritic crystals of enstatite also occur in them. The olivine of the chondrules occurs as porphyritic, anhedral masses and with well-defined prismatic outlines. Considerable fracturing is found in both cases. The fibrous enstatite may grow around and partially envelope the olivine prisms. One small chondrule is built up of three ray-like bundles of chrysolite which extinguish alternately in polarised light.

The groundmass is made up of a confused aggregate of olivine and enstatite granules together with nickel-iron, and an opaque mineral with a bronzy lustre, presumably troilite. A very small amount of an opaque, black, lustreless substance also occurs, which may be carbonaceous matter. Well-marked porphyritic crystals of olivine and enstatite are present in the groundmass, the former mineral sometimes building small rounded clusters which appear to be a form of incipient chondritic structure. The smaller grains of the metallic minerals are usually found either at the edges of and enclosed within the silicates, usually the enstatite of the chondrules, or else disposed outside, and close to their edges. The larger grains do not possess this arrangement, but appear to be deposited anywhere, though they are sometimes in contact with the larger olivine crystals of the groundmass. Most of the granules have rounded outlines, but some of the larger ones are more irregular in shape. The troilite grains are smaller and of less frequent occurrence than those of nickel-iron.

When examined under the microscrope the crust is seen to form a well marked band ·25 mm. thick. The outer part of this consists of a thin, darker, fusion line which has a rough outline. It is followed by a less opaque zone in which the forms of chondrules can be distinguished.

The meteorite has been added to the collection in the Geological Survey Museum where it bears the number 254, and brings the total of recorded falls from the Indian Empire, therein represented, to 75.

Other known gold deposits that were not visited occur in the Chaungyi-chaung valley, and at the head of the Uyu near the military post of Hoang-pa. The deposits in the Chaungyi-chaung are found near the villages of Mansi, Payindaung and Mingon, and also in the upper portion of the river on the borders of the Katha district. These have been examined in recent years by several European prospectors and have been considered valueless.[1] As far as I am aware there are no gold-bearing gravels in the valleys of the Yu and Myittha.

I am glad of this opportunity to express my appreciation of the great courtesy with which I was received by all residents in the Upper Chindwin, whether official or non-official. I am especially indebted to Mr. J. M. Wright, I.C.S., whose generous advice and assistance made my stay an exceptionally pleasant one.

PHYSICAL GEOGRAPHY AND GEOLOGY.

The rocks met with in the Upper Chindwin sub-division and in Singkaling Kanti State may be roughly classified as follows :—

Recent gravel and sand banks.
Older gravels . ? Pleistocene.
Tertiaries.
Schists. ? Makwari Series.
Serpentine. Cretaceous.

The Older gravels.

The *older gravels*, probably of Pleistocene age, are well exposed along the course of the Chindwin at numerous points between Kindat and the northernmost limit of Singkaling Kanti State. They are especially well seen near Naung-san-kyin, Maungkhan, Tazôn, Tamanthe and Maubin, and rest unconformably upon the Chindwin Tertiaries.

Along the whole of this stretch of the river the deposit is constant in character, being a coarse conglomerate of well rounded pebbles, from two to four inches long, set in a ferruginous sandy matrix which forms but a small proportion of the bulk. The pebbles are mostly quartzites, quartz-schists and phyllites, but above Homalin pebbles of serpentine are sometimes found. At Maungkhan one pebble of an augite-bearing lava of an andesitic

[1] J. M. Maclaren. Confidential Report, Geol. Surv., India.

nature was obtained. This when cut shewed augite phenocrysts frequently largely altered to serpentine, embedded in a glassy base containing small granular crystals of augite.

The matrix of the Pleistocene gravels may be regarded as mainly derived from the breaking up of the soft Tertiary sandstones.

Most of the pebbles have certainly come from the upper reaches of the river, where ancient schists and gneisses occur together with serpentine.

The pebbles in the *older gravels* along the Uyu river near Kyobin seem to have come from the Katha district in the region drained by the Chaungyi-chaung, and include much decomposed igneous rocks probably derived from a northward extension of the Tertiary complex of the Wuntho district.

The Uyu gravels, which at Teingon and Kyobin are over 150 feet thick and completely mask the older rocks, are much finer in texture than those along the main river and consist of lenticles of gravel and sand in about equal proportions.

These *older gravels* everywhere contain gold and platinum, but only along the Uyu river is the occurrence worthy of any consideration.

The Tertiary system.

Rocks of Tertiary age occupy the whole of the Upper Chindwin sub-division, and extend from the Kabaw Valley on the west to the Mu Valley on the east.

The beds lie in a broad syncline with a north and south axis, along the western limb of which the Chindwin river flows. Along the whole course of the river the prevailing dip is to the east, giving rise to steep escarpments on the left bank, with corresponding dip slopes on the right. Numerous whirlpools occur where, as between Masein and Kalewa, the river takes sharp bends cutting across the strike before resuming its southerly course. Along the western flank of the syncline the Tertiaries dip steeply off the complex of so-called Axials in Manipur State,[1] while the eastern limb is known from the researches of F. Noetling[2] in the Wuntho district, where Irrawadi sandstones dip W. off the igneous massif of the Maingthong Hill Tracts.

[1] R. D. Oldham, *Mem., Geol. Surv., Ind.*, Vol. XIX, pt. 4, 1883.
[2] F. Noetling, *Rec., Geol. Surv., Ind.*, Vol. XXVII, pt. 4, 1894.
Storey, Annual Report, *Rec., Geol. Surv., Ind.*, 1896.

There is no available information regarding the Chindwin syncline but it is certainly composed of a number of minor folds similar to that recorded in the Lower Chindwin area, W. of Kani, by E. H. Pascoe.[1]

As my work necessarily confined me to the river I am unable to enter into a discussion of the classification of the Chindwin Tertiaries. Much valuable work has, however, been done in this region by the geologists to the Indo-Burma Petroleum Company, and it is to be hoped that an account of the geology may shortly be published.

The Schists and Serpentine.

The Upper Tertiaries extend northward through Singkaling Kanti to the village of Selon, beyond which they come to an abrupt end against a deeply dissected mountainous area occupied by highly metamorphosed and cleaved sediments. This junction where crossed along the course of the Chindwin river trends north-west and south-east, as indicated on the sketch map forming Plate 23.

The river runs through a rocky gorge which was followed for about ten miles to Kyauk-se, where rapids prevent further progress. Along this stretch the schists strike north-east and south-west, and dip north-west at angles between 45° and 60°.

It is important to note that these altered sediments lie exactly on the strike of the Makwari series as mapped by E. H. Pascoe around Sarameti.[2]

The junction between the schists and the Upper Tertiaries is obscured by alluvium, but may be taken as marking the original limit of deposition in this direction.

The only rocks met with *in situ* were highly cleaved phyllites with bands of ferruginous sandstones containing pebbles here and there, but never approaching a regular conglomerate.

Of far more importance are the boulders found in the gorge itself and on the sand bank at Maubin. These have all undoubtedly come down from the higher reaches of the river and furnish us with a little information regarding the geology of an entirely unknown tract. A great many large boulders of serpentine occur, which are similar to the intrusions described by E. H. Pascoe

[1] E. H. Pascoe, *Mem., Geol. Surv., Ind.*, Vol. XL, p. 1, pp. 141-145.
[2] E. H. Pascoe, *Rec., Geol. Surv., Ind.*, Vol. XLII, p. 261 (1912).

near Sarameti. There can, therefore, be no doubt that the belt of intrusive serpentine which occurs along the inner boundary of the so-called Axials of the Arrakan Yoma, Manipur, and the Naga Hills, extends to the west of the Tertiary basin and crosses the Chindwin river a few miles above the Kyauk-se rapids. One boulder of the serpentine [26/808][1] contains rhombohedra of magnesite.

Another rock occurring as boulders is quartz-hornblende schist, the hornblende being referable to the variety known as pargasite.

A boulder of strongly foliated gneiss [26/803] seems to point to the existence of an Archaean area in the Hukong valley.

[26/813] A conglomerate of well-rounded pebbles in a grey gritty matrix. Under the microscope it is seen to consist of fragments of lava and quartz-schist embedded in a matrix of quartz grains and decomposed ferromagnesian matter. The lava fragments are of two kinds, the one, a light isotropic glass impregnated with chalcedony; the other, a rusty brown isotropic glass full of small spherulites. The spherulites give a black cross between crossed nicols, and are probably filled with quartz and felspar; they have a distinctly linear arrangement due to flow. An examination of a slide of the Makwari conglomerate recorded by E. H. Pascoe, shewed that it also contains fragments of the same isotropic glass with spherulites and in considerable quantity, a fact which perhaps justifies the assumption that the Makwari conglomerate, like the serpentine, is present in the upper reaches of the Chindwin river.

The fragments included in the conglomerate are not the only indications of acid lavas which were obtained; two boulders, presumably of the same rock, were picked up in the river below Kyauk-se.

[26/812.] This rock is green in colour, resembling serpentine in a hand specimen; it is isotropic, and appears to be a devitrified lava. The specific gravity is 2·876. In thin sections curious nests and strings of lath-shaped felspars are seen, which give a maximum extinction angle of 19° (measured on the long axis of the microlites). Many of the crystals are twinned and are probably referable to albite or andesine-labradorite.

[26/804.] A reddish devitrified lava, isotropic, and strongly impregnated with chalcedony. Specific gravity 2·618.

[1] The numbers are those under which the specimens have been registered in the rock collections of the Geological Survey of India.

The occurrence of these fragments of lava is of considerable interest, pointing as it does to the existence of an hitherto unknown series of fairly acid lavas between the Naga Hills and the Hukong Valley.

E. H. Pascoe fixes the age of his Makwari conglomerate as post —Upper Cretaceous on the ground that it contains fragments of serpentine, and if this be so, these acid lavas must be at least as old as the Upper Cretaceous. Beyond that there are no means of fixing their age.

MODE OF OCCURRENCE AND ORIGIN OF THE GOLD.

In both the Pleistocene terrace gravels and in the recent river deposits, the gold occurs in thin laminae and scales roughly square or oval in outline, the largest pieces met with being only about one-tenth of an inch in length, but the flakes were in the majority of cases only half this size. A considerable proportion of the gold occurs in fine specks, and "float" gold is always present. Under the microscope the flakes are strongly pitted and frequently quite ragged in outline. In no case was anything approaching a nugget found, and no quartz or other vein matter was ever seen attached to the gold. It may therefore be assumed that the source of the gold is nowhere near the present site of the gravels.

Platinum has been detected in almost every locality but in very small amount; its mode of occurrence is the same as that of the gold. Together with the platinum occur other rarer members of the group such as osmiridium.

The bulk of the heavy residue is composed of magnetite, but zircons and garnets are also common.

J. M. Maclaren[1] gave it as his opinion that the auriferous gravels of the Chindwin "together with their contained gold, are derived from the Miocene sandstones and conglomerates through which the river runs, and there is, therefore, no likelihood of richer deposits being found higher up the river." With regard to the deposits in the Uyu river he remarks "There can be little doubt, from the position of the Kyobin gravels that their gold has been derived from the Chaungyi-chaung rather than from the Uyu river. The

[1] J. M. Maclaren, *op. cit.*, pp. 9, 11.

Chaungyi gold, again, is itself probably derived from veins in Tertiary igneous rocks towards the head of the stream."

With the above statements I am in general agreement. Such gold as is present in the recent river gravels, is amply accounted for by the gold occurring in the *older gravels* now being cut into by the Chindwin river. The origin of the gold in the *older gravels* themselves is a more difficult question upon which it is useless to speculate, while the geology of the northern frontier of Burma remains unknown.

The question of the origin of the platinum, which is closely bound up with that of the gold, is one that presents serious difficulties. In almost every case in which platinum has been traced to its parent rock it has been found to occur in chromite segregations, associated with serpentines.[1] As we have seen, a belt of serpentine does extend from the Andamans, more or less continuously, through the Arrakan Yoma, Manipur, the Naga Hills and the upper part of the Chindwin drainage. In the Andamans chromite is associated with this serpentine[2] and I found small pockets of chromite in the serpentines near the village of Sibong in Manipur.[3] It is not impossible, therefore, that somewhere to the north there may be workable deposits of chromite associated with serpentine intrusions, and that such chromite deposits may prove to be the source of the platinum and platinoid metals occurring in the *older gravels* of the Upper Chindwin.

RESULTS OF THE ASSAYS.

The assays were all carried out by Mr. A. K. Banerji, Assistant Curator, under the supervision of Mr. J. Coggin Brown, Curator of the Geological Museum and Laboratory. I am deeply indebted to these officers for their work, which entailed no small amount of labour owing to the extremely refractory nature of many of the concentrates.

1 J. F. Kemp. The Geological Relations and Distribution of Platinum and associated metals. *Bull. U. S. Geol. Surv.*, 1913.
R. A. Farquharson. The Platinum Gravels of Orepuki. *Trans. N. Z. Inst.*, Vol. XLIII, pp. 448-482, 1911.

2 G. H. Tipper. *Mem., Geol. Surv., Ind.*, Vol. XXXV, pt. 4, 1911.

3 Sibong is the first stage on the road from Tamu to Imphal (Manipur).

The average amount of gold in the Helaw gravels, which may be taken as a type of the recent river gravels, is only half a grain to the cubic yard. Under any conditions this may be regarded as extremely disappointing, and in view of the natural disadvantages of dredging in such a river as the Chindwin, coupled with the fact that the gold is limited to the upper two feet or so of the banks, no hope whatever of successful exploitation can be entertained.

The Kyobin deposit, which seems to be the best of the *older gravels*, gave decidedly better results than any of the recent alluvium. In this case, however, the payable gravel is so intimately mixed with barren sand, and so inconstant in character, that both would have to be taken together. The mass average of the deposit is far too low to enable work to be carried on at a profit.

In my opinion, the gold-bearing alluvium of the Chindwin can only be worked on the small scale at present adopted by the local inhabitants, who by years of experience are aware of the position of the richer pockets.

SHAN GOLD-WASHING METHODS.

There are only two places where gold-washing is at present being seriously carried on. One of these, namely Helaw, is on the main river, the other being on the Uyu river in the neighbourhood of Kyobin.

In the first locality recent river gravels are washed, and the method practised has been described by J. M. Maclaren[1] as follows :—

> "As soon as the highest point of the island is uncovered after the floods, it is attacked by the native washers who remove only the upper gravel to a depth of from 8 inches to a foot. The gravel is screened through bamboo sieves of about $\frac{3}{8}$ inch mesh, and the stones thrown to one side. The screened gravel is then carried in baskets to the waterside, where it is thrown on a smaller mesh ($\frac{1}{4}''$) screen laid at the head of an inclined shallow wooden trough 4 feet long. The trough is supported on a forked stick at the upper end and rests in a slot in a stake at the lower end. A fall of about 6 inches in the total length is given to the trough.

[1] J. M. Maclaren, *op. cit.*, p. 7.

The gravel thrown on the screen is washed through with water from a dipper made of two bamboo nodes lashed side by side, and the coarser stones remaining are removed with the screen. Washing with water is continued until the heavier sands alone remain, a low transverse ridge at the bottom of the trough acting as a riffle. When, after repeated washings of sand, sufficient concentrates have accumulated these are washed in a batea or round shallow wooden tray and handed over to an assistant, who separates the gold from the magnetite, etc., with which it is associated. Four women (nearly all the washers here are women) work in a party, two to dig and carry the gravel, one to work the long trough and one to complete the washing in the batea."

The trough in use at Kyobin differs from that at Helaw in having four or five transverse riffles at the lower end, while that used in the Hukong Valley by the Kachins is grooved all the way down. It would seem that the use of the riffle as a gold catching device is being slowly introduced into the Chindwin from the Hukong Valley, and doubtless ultimately from China.

The native method of working the gravels at Kyobin is a form of ground sluicing (*shwemyaung*). Water is brought to the foot of the gravel cliffs to be worked by an elaborate system of canals about 1½ feet across and a few inches deep. In places, however, these canals have been cut much deeper in order to cross an elevation. At Taung-ni, for example, the canal at one place is only 1½ feet wide, but has been cut through a gravel ridge to a depth of 8 feet. There are no less than five canals on the Kyobin side of the river, namely, the Hwe-zadaik, the Lingyi, the Taung-ni, the Haung-hin or Kyauk-myaung; and the Hwe-ma-mon. The aggregate length of these canals is about 2½ miles. The Hwe-zadaik runs at a level about 5 feet higher than the Hwe-ma-mon and keeps parallel to it for most of its length. At Teiñgon there is one canal, the Hwe Latak, which is approximately ½ mile in length. The courses of these canals may be seen from the map, plate 24, fig. 1.

The gravel is dug from the cliffs with wooden spades tipped with iron and laid along a tail-race which is connected with one of the canals. Water is then allowed to run over the loosened gravel for some days, at the end of which the bottom of the tail-race is cleaned up, the pebbles being thrown on one side, and the sand washed with trough and batea in the usual way.

The innumerable mounds of pebbles thrown aside from old tail-races testify to the energy with which the gravels have been exploited in past times.

DETAILED DESCRIPTION OF GOLD DEPOSITS.

For convenience of description the area under review will be sub-divided as follows :—

A. The main Chindwin River.

B. The Uyu River.

The gold deposits themselves are found in—

(1) the recent river gravels;

(2) the *older gravels*, probably of Pleistocene age.

A. THE MAIN CHINDWIN RIVER.

1. The recent river gravels.

The lowest point on the river where any gold washing is carried on is at Alôn (22° 14′ : 95° 10′). The villagers only work here spasmodically during the rains, and the deposit is of no value.

Alôn.

I am informed that at Thazi, 15 miles north-east of Monywa, a little gold is won in the bed of the torrential stream descending from the Mu-Kyaukka watershed and emptying itself into the Chindwin below Alôn.

Thazi.

Kani.

Gold and platinum have also been reported from Kani.[1]

With these two exceptions, I do not know of any deposits away from the main river. Other minor deposits sometimes worked by the local people are in the upper waters of a small stream flowing into the Chindwin on the left bank about 7 miles below Kalewa,[2] and at Maulaikgyi, 6 miles below Kindat.

Maulaikgyi.

[1] *Burma Gazetteer*, Lower Chindwin District, p. 116.

[2] J. M. Maclaren, *op. cit.*, p. 7.

The two gravel beaches at Maulaikgyi were tested with the batea and found to be inferior to those at Helaw to be described immediately.

Helaw and Gyogon.

The recent river gravels near Helaw are unquestionably superior to any others found along the course of the river Chindwin, and were therefore thoroughly tested as a typical example.

It will be seen from the sketch-map (plate 24, fig. 2) that we have here a stretch of gravel and sand about 1½ miles long composed as follows :—

The Helaw Island, somewhat over a mile in length, of which the upper half is covered with good gravel, the rest being sand, the Gyogon Island, likewise composed of good gravel in its upper half, and the Ywatha beach.

The pits put down show conclusively that the gravel here is only a surface deposit of no great thickness overlying sand devoid of gold. The gold is deposited after the rains in the local eddies formed by the surface deposit of boulders, and most of it, therefore, occurs at the head of each island or beach and only to a depth of about one foot. In fact my tests go to show that not only are the surface gravels alone rich in gold, but, that even these are only rich at points which mark the heads of the islands at successive stages in their emergence after the Monsoon. This surface concentration is doubtless due to the fact that the floods of one rainy reason scatter the gold deposited at the end of the previous one.

I am therefore in entire agreement with J. M. Maclaren, who remarks "that the only possible hope of success in dredging here lies in scraping up a surface layer of 8 inches to a foot, an operation that means a great reduction in the lifting capacity of a dredge, since the buckets will rarely fill."

The more exhaustive tests which I was able to make show that, even in this surface layer, the gold content is not constant and may be absent altogether. In view of this, I am unable to hold out any prospects of successful dredging.

Helaw Island.

Three shallow pits were sunk at the head of the island to test the surface gravels. In each case the dimensions were 6 ft. by 3 ft. and the depth 1½ ft. At this depth sand was encountered which was not worth washing. There is a bar at the head of the island and the stones on the surface are unusually big, most of them ranging from 6 inches to a foot in length.

Pit 1. The cubic yard gave ·552 grains of gold.

Pit 2. The cubic yard gave ·212 grains of gold.

Pit 3. The cubic yard gave ·568 grains of gold.

Pit 4.—3 ft. square and 6 ft. deep.

The whole of this pit yielded only traces of gold.

Pit 5.—3 ft. square to a depth of 9 feet.

First 3 ft., *i.e.*, 1 cubic yard gave 1·313 grains. This was good gravel containing about 35% of stones over 2 inch.

3′-6′. Very fine gravel: ·016 grains per cubic yd.

6′-9′. Coarse sand with only a trace of gold.

Pit 6.—3′ square to a depth of 9′ 6″ when water was encountered.

First 3′, *i.e.*, 1 cubic yard: ·566 grains

3′-8′ 6″: ·107 grains per cubic yd.

The last foot was in sand with no gold.

Pit 7.—1 cubic yard from the surface gave ·016 grains of gold. The proportion of stones over 2″ was 37%. A pit 3 ft. square was also sunk here to a depth of 2′ 4″, when water stopped the excavation. The 21 cubic ft. so obtained yielded only ·562 grains, or ·72 grains per cubic yd., and the greater part of this came from the uppermost foot.

Several surface washings at other points on the island show conclusively that the gold is distributed very irregularly. At one spot surface washings gave ·9 grains to the cubic yard, while in another only 20 ft. away the gold content was ·246 grains per cubic yard.

I quote the record of the following pit put down by Dr. Maclaren.[1]

"As a typical example a pit, 9 feet square, was sunk. The gravel from the first $2\frac{3}{4}$ feet in depth was washed in one lot. The $6\frac{3}{4}$ cubic yards so obtained yielded only $2\frac{1}{2}$ grains or ·374 grains per cubic yard. A further depth of 2′ 2″ or $6\frac{1}{2}$ cubic yards yielded only at the rate of ·12 grains per cubic yard, but the gravel had given place to sand at a depth of $3\frac{1}{2}$″ from the surface, and from that depth to the total depth ($6\frac{1}{2}$ feet) permitted by water the pit was continued in sand. In the sand no gold whatever was found. Washings from the surface gravels in the same places showed returns of 4—8 grains,. . . ."

[1] J. M. Maclaren, *op. cit.*, p. 8.

Gyogon Island.

The upper half of this island is composed of good gravel and was tested by means of pits put down at intervals of about 100 yards at the points shown on the map (Plate 24, fig. 2).

As in the case of the Helaw island the gold is more or less confined to the uppermost foot, and in places even this upper layer is decidedly poor. The gravels are everywhere underlain by sand but are thickest at the head of the island, gradually thinning to the rear till they become a mere layer of pebbles resting on sand.

Pit 1—

A pit 6′ by 3′ was carried to a depth of 1½′, the cubic yard giving ·56 grains of gold. From this depth on to the total depth of 8½′ the pit was made only 3′ square. At 8′ barren sand was reached.

The cubic yard from 1½′ to 4½′ gave ·1 of a grain.

The gravel from 4½′ to 8½′ gave ·09 grain per cubic yard.

Pit 2—

3′ square to a depth of 7′ 8″, when barren sand was encountered.

First 3′, *i.e.*, 1 cubic yard gave 1·3 grains.

3′ to 7′ 8″, *i.e.*, 1$\frac{5}{9}$ cubic yards, gave ·088 grains, or ·056 grains per cubic yard.

Pit 3—

3′ square to a depth of 6′ 3″, when water was met.

First 3′ 5″ gave 0·335 grains per cubic yard.

3′ 5″ to 6′ 3″ gave only ·035 grains per cubic yard, but from 4′ 7″ the pit was in sand.

Pit 4—

3′ square to a depth of 5′, when water stopped excavation.

First 3′, *i.e.*, 1 cubic yard, ·022 grains.

The remaining ⅔ cubic yard contained practically nothing.

Pit 5—

6′ by 3′ to a depth of 1½′, the cubic yard giving ·566 grains of gold.

From 1½′ to 6′ the pit was only 3′ square, and the gold contents ·05 grains per cubic yard.

At 6′ the pit was stopped in sand.

Pit 6—

The gravel here was only 1′ thick, being followed by barren sands. One cubic yard from the surface here gave ·826 grains.

Pit 7—

3′ square to a depth of 6′, sand reached at 5′; all, washed in one lot, giving ·216 grains per cubic yard.

Pit 8—

3′ square to a depth of 6′ 10″, sand reached at 5′ 5″. First 3′, *i.e.*, 1 cubic yard, gave ·442 grains.

3′ to 6′ 10″ gave ·07 grains to the cubic yard.

Ywatha beach.

One cubic yard of gravel was washed from the surface of this beach and yielded 1·174 grains of gold.

Dr. Maclaren[1] states that surface washings from the long beach below the village of Ywatha gave as much as 38 grains of gold per cubic yard of *screened* material. Here also the rich gravels are confined to the upper 1½′, and give place downwards to sand.

Various minor localities.

Between Helaw and Homalin the river mostly deposits sand, and there are no gravel banks worthy of consideration. Where gravel exists it forms a thin layer, usually only some 2″ to 3″ thick, on top of sand. Small patches of gravel may be seen at low water near Nat-ein-sin, Non-yin, Naung-san-kyin, and Minbwe.

The only tests made were at Naung-san-kyin and the values obtained were excessively poor.

Above Homalin there are gravel beaches at Pin-pa-nu and Pè-bin opposite Maungkhan. There are no native washers at either place.

The Pin-pa-nu beach consists of a layer of fairly large stones, from 3″ to 6″ long, overlying sand. The gold is very fine and hard to catch, and pan tests gave only two or three fine colours to the dish.

The head of the Pè-bin beach contains many large stones up to 9″ in length, but behind the gravel becomes gradually finer till it passes into sand. 1 cubic yard from the surface at the head of the island gave ·044 grains of gold. As usual the gravel rapidly gives place downwards to sand.

The next occurrence of gravel is at Limpa (25° 52′ : 95° 40′), and here too the main part of the island is sand. Pan tests at several points gave the merest trace of gold, and one cubic yard

[1] J. M. Maclaren, *op. cit.*, p. 8.

from the surface, at the richest point found, yielded only ·346 grains.

A little fine gravel is seen at Hemsun, but it gave only a trace of gold to the pan.

At the village of Pawmang, ½ mile below Kanti, there is a small gravel beach. Pan tests shewed traces of gold and platinum.

There are two gravel areas in the river at Maubin, one below, and the other above, the village. A few old women used to work the former a few years ago. 1 cubic yard from the surface of the lower exposure, opposite the village of Let-pantha, gave ·63 grains of gold. 1 cubic yard from the surface of the gravel above Maubin gave ·084 grains.

Similar deposits occur still higher up the river at Labaingaik, 10 miles above Maubin, and at Selon.

Pan tests at Selon gave the usual trace of gold. Above Selon the Chindwin sandstone country ends, and the river runs through a precipitous gorge.

2. The older gravels.

Pan tests at several points along the outcrop of the older gravels show that gold is always present, but invariably in such small quantity as to be far too poor to be worked even by native washers.

One cubic yard at Maungkhan gave ·28 grains of gold.

One cubic yard at Kabani, near Naung-san-kyin, gave ·145 grains.

These older gravels along the course of the main river are only of interest as showing the source of most, if not all, of the gold in the recent gravel banks.

B. THE UYU RIVER.

1. The recent river deposits.

KHAUNG-NGO.

This is the only locality on the Uyu where the recent river deposits are worked for gold, the washing being conducted on sand-banks.

At the time of my visit there were some thirty men and women washing with bateas at Khaung-ngo itself, and a smaller number at Sike-puaikenoy, a mile lower down stream.

At Pa-thet, ¼ mile above Naung-khet, there is another sand-bank where a few women work.

The villagers at Khaung-ngo are very expert as will be seen from the following.

I engaged 6 women who washed for me for 5 hours, during which time they washed 626 panfuls of the sand and obtained 8·228 grains of gold. As a rough estimate we may take the 626 pans as equal to 4 cubic yards, which gives an approximate average of 2·057 grains to the cubic yard.

2. The older gravels.

Kyobin.

The gold at Kyobin occurs in false-bedded gravels and sands which form a terrace averaging 50′ in height and standing back ½ to ¾ mile from the Uyu river.

The gravels are everywhere covered with jungle composed mostly of bamboo. The undergrowth is considerable and any attempt to dredge here would have to meet this initial difficulty. A paddock would have to be excavated and the water to float the dredge brought from the Uyu; the height of the cliffs might be a source of trouble, as there would be danger of their falling in and fouling the bucket ladder.

The gravel-beds are exceptionally fine and beyond a few pieces of fossil wood, practically no stones occur of a greater diameter than 3 inches. The vast majority of the pebbles run from 1″ to 1½″ in greatest length. The deposit consists of gravel and sand in about equal proportion and both occur in lenticles, no constant horizon being present. Lenticles of clay occur here and there and likewise small clay-galls. The amount of clay is, however, very small, the only horizon at which anything approaching a regular bed was met being at a height of 90 feet above the level of the Hpongyi-kyaung, Kyobin.[1] This clay band forms the base of the cliff at the head of the Hwe-monhlaing stream and also runs along the floor of the Taung-ni exposure. It is not constant, however, being absent in places. Along the line of pit 13, at Lingyi, for

[1] The level of the road outside the Hpongyi-kyaung, Kyobin, has been taken as a convenient datum line.

instance, only some 130 yards from its outcrop at the head of the Hwe-monhlaing, it is replaced laterally by gravel. No difficulty therefore need be anticipated from clay.

The thickness of these deposits is considerable and bed-rock is nowhere exposed, neither has it been struck by any of the pits put down by me.

The lowest horizon washed was in pit 8 at Hwe-ma-mon at a height of 13′, and the highest in pit 3, at Hwe-zadaik at a height of 103′ above the Hpongyi-kyaung datum. This gives a thickness of at least 90′ for the deposits, and in places there are probably over 150′ of sands and gravels. Along the foot of the jungle covered gravel terraces are swamps covered with *kaing* grass. The surface here is clay and two pits sunk in this passed through 2′ of clay before being stopped by the influx of water. Gravel occurs below this clay, however, and is probably a re-wash of the high-level terrace gravels. This low-level gravel may well be richer than the terrace gravels, but could not be tested without the help of a drill.

My examination was necessarily confined to the gravel terraces which were tested by means of pits and cuts in the face of the cliffs. Water is extremely scarce away from the river, and the gravel had in every case to be carried to the canals made by the Burmese washers. All the gravel was panned under my personal supervision.

Reference to the map (Plate 24, fig. 1) will show the localities where the Burmese workings occur and also the canals by which water is brought to them. Each cliff is named from the canal which feeds it.

Hwe-Zadaik.[1]

The Hwe-zadaik cliff is about 40 feet high on the average, and extends for about 250 yards in a north and south direction. The following tests were made at the points indicated on the map, and the record of the pits and cuts is given in plate 25.

Pit 1—

This pit passed through 6′ of soil which was not washed, but contains a little gold and is not clayey.

[1] *Hwe* (Shan) stream, *zadaik* (Burmese)-the chest in which the sacred books of Gautama are kept. The legend runs that when this locality was first washed so much gold was obtained that the washers were able to present a chest to the Kyobin *hpongyi kyaung*.

At 25′ 6″ a thick sand was reached and the pit stopped. The gold from the 19′ 6″ of gravel and sand was washed in one lot and yielded only 1·413 grains per cubic yard.

Up to a depth of 16′ 7″ the gravel was very poor, but from 16′ 7″ to 23′ 6″ more gold was met.

A separate cut was therefore made to test this richer horizon and gave an average of 2·562 grains per cubic yard (cut 1).

Pit 2—

Total depth 36 feet.

The soil was 1′ 6″ thick, and the next 29′ 2″ was washed in one lot, giving only ·415 grains to the cubic yard.

Almost all the gold was obtained from two thin bands of gravel, each a foot thick, between 13′ and 14′, and 16′ and 17′ respectively.

The remaining 5′ 4″ gave 1·299 grains per cubic yard, and correspond to the gold-bearing horizon at the bottom of pit 1.

Pit 3—

Total depth 31′ 3″.

Soil, not washed, 3′.

Gravels from 3′ to 26′ 9″ contained ·249 grains per cubic yard.

26′ 9″ to 27′ 7″, stiff light coloured clay.

Gravels from 27′ 7″ to 31′ 3″ contained ·117 grains of gold per cubic yard.

The whole of the gravel passed through by this pit was very poor.

Pit 6—

Total depth 28′.

Soil, 5′: contained 1·6 grains of gold per cubic yard.

Gravels, 5′ to 13′ 8″: contained ·97 grains per cubic yard.

White quartz sand with no gold, 13′ 8″ to 18′.

Sand, 18′ to 24′: ·77 grains per cubic yard.

A band of clay about 1′ 3″ was met in this portion of the pit.

White quartz sand with no gold, 24′—28′.

A thin band of fine gravel at a depth of about 6′ 9″ was the only part of this pit that was of any value.

Excluding the soil the mass average for the gravels and sands passed through by my pits at Hwe-zadaik works out at ·69 grains of gold per cubic yard, a most disappointing result.

The local washers confine their attention to the six or eight feet of the richer gravel passed through in the lower part of pits 1 and 2.

Hwe-ma-mon.[1]

The Hwe-ma-mon cliff is about 200 yards south of the Hwe-zadaik and averages 30′ in height.

Pit 4—

Total depth, 29′ 9″.

Soil, not washed, 1′.

Gravel and sand, 12′ 7″, contains ·432 grains per cubic yard.

13′ 7″ to 22′ 6″: 2·502 grains per cubic yard.

22′ 6″ to 29′ 9″: 5·7 grains per cubic yard.

Pit 8—

This was sunk at the level of the base of pit 4 in order to test the lowest gravels.

It passed through 5′ 1″ of soil with the merest trace of gold, followed by 2′ 6″ of gravel containing 2·328 grains per cubic yard. Further excavation was stopped by water.

Pit 5—

Total depth, 26′ 10″.

Soil, 6′, containing 1·08 grains per cubic yard.

6′ to 12′ 7″: ·741 grains per cubic yard.

12′ 7″ to 22′ 7″: ·166 grains per cubic yard.

22′ 7″ to 26′ 10″: ·36 grains per cubic yard.

A cut was made at the base of the cliffs to continue this pit to a lower level.

28′ to 38′: 2·682 grains per cubic yard.

The mass value for the Hwe-ma-mon gravels works out at 2 grains per cubic yard.

Two hundred yards or so south of Hwe-ma-mon there are three smaller *shwe-myaung* workings visited by the villagers during the rains only. During my visit, water was not available within a reasonable distance, and they were not therefore tested, but there is no reason to believe that they differ from the other localities.

Lingyi.[2]

The Lingyi cliffs average 35′ in height and extend in a north-east and south-west direction for some 200 yards. This locality was

[1] *Ma-mon* (Shan)-mango.

[2] Lingyi: *lin* (Burmese)-a trough, *gyi* (Burmese)-big.

The Lingyi canal was formerly carried across the swamp one-third of a mile W. of Taung-ni by means of a trough reported to have been 200 yards long and made of matting laid on bamboo supports. The trough is indicated upon the map, although no trace of it now exists. The canal is now brought along the contour at the edge of the jungle instead.

extensively worked in past times, but is not much visited by the present generation and is consequently overgrown. The valuable portion is a gravel band in the middle of the cliff, and two cuts were made with the object of testing this.

Cut 10—

This cut was 3′ by 2′ through 10′ of good gravel.

The 60 cubic ft. so obtained yielded 6·474 grains, an average of 2·81 grains to the cubic yard.

Cut 11—

Along the line of cut 11 the gravel lenticle had swollen to a thickness of 17′ 6″, and the cut, made vertically through, was washed in two lots.

The upper 8′ gave ·645 grains per cubic yard.

The remaining 9′ 6″ gave ·945 grains per cubic yard.

This gravel horizon is sandwiched between barren sands.

Pit 12—

This pit was sunk 150 yds. S. W. of the Lingyi cuts and passed through 8′ of soil without reaching gravel.

Pit 13—

The first 9′ 8″ passed through very poor gravel containing only ·36 grains per cubic yard.

The next 2′ 6″ was in very rich gravel yielding 5·556 grains per cubic yard.

A reference to the map will show that the local washers have put down a great number of pits at this point in order to remove this rich gravel occurring at a depth of 10′.

I was unable to continue this pit owing to lack of time, but it may be stated with certainty that this band, like all the other rich gravels, is of no great extent or thickness, being merely a lenticle. This is clearly shown by the fact that at the head of the Hwe-mon-hlaing stream, only some 500 yards to the north, this horizon is represented by clay overlying white quartz sand with absolutely no gold.

Taung-ni.[1]

This is the highest cliff of all, being quite 60 ft. high in places. It is capped by some ten feet of red ferruginous soil and sand, hence the local name.

[1] *Taung* (Burmese) hill—*ni* (Burmese)-red.

The cliffs extend for over one mile in a north-east direction, but are much lower at the northern end.

The base of the quarry is a band of yellow clay which throws out springs feeding the swamps below. This clay is on exactly the horizon of the clay bed at the head of the Hwe-mon-hlaing.

Most of the cliff is composed of sand, which is ferruginous above, but a pure white quartz sand below. In the lower part there are, two thin gravel bands worked by the Shans, and two cuts were made to test these.

Cut 12—

This passed through 8′ of gravel and sand and gave ·617 grains of gold per cubic yard.

Cut 13—

This passed through 10′ 4″ of gravel and sand and gave 3·97 grains per cubic yard.

Hwe-mon-hlaing.[1]

At the head of the Hwe-mon-hlaing there is a cliff of gravel and sand resting on a stiff yellow clay band. Below the clay are barren sands, the only gold-bearing gravels exposed being above it.

Two cuts were made through the upper part as far as the clay.

Cut 9 (a)—

Soil 6′ 7″, ·209 grains per cubic yard.

Gravel, 6′ 7″ to 15′, 1·71 grains per cubic yard.

Cut 9 (b)—

This cut beginning in fine gravel a little above the base of cut 9 (*a*), was continued for 9′ to the surface of the clay: gold content, 2·837 grains per cubic yard.

It will be noted that, so far as any definite horizon can be said to exist in so highly false-bedded a deposit, there is a tendency for concentration of the gold in the gravels at about the level of this clay band, 87 feet above the datum line of the *hpongyi-kyaung*, Kyobin.

Kyauk-myaung or *Haung-hin.*[2]

There are two cliffs worked here about ¼ mile due east of the *hpongyi-kyaung*, Kyobin. The highest cliff is immediately below the

[1] *Mon-hlaing* (Shan) = a bat.

[2] *Kyauk* = stone, *myaung* = trench (Burmese); *haung* = trench; *hin* = ton (Shan).

Pagoda and was tested by several cuts at different levels and by one shallow pit, so as to get an average for the whole.

Pit 9—

This passed through 5′ 6″ of soil which was not washed, being very poor in gold and somewhat clayey.

From 5′ 6″ to 8′, gravel was met with, containing ·387 grains per cubic yard.

From 8′ to 13′ 6″, clay and sand mixed in varying proportion, with no gold.

Cut 4—

13′ to 25′. Sand: gold content: ·196 grains per cubic yard.

25′ to 35′. Gravel: gold: 1·56 grains per cubic yard.

36′ to 46′. Gravel: gold: ·62 grains per cubic yard.

Cut 5—

46′ to 56′. Gravel with some clay galls in the middle: 1·518 grains of gold per cubic yard.

The second cliff a little further west was tested by a pit, supplemented by a cut in the lower part.

Pit 7—

1′ to 6′ 9″. Gravel: 1·934 grains per cubic yard.

6′ 9″ to 12′ 8″. Gravel: ·429 grains per cubic yard.

12′ 8″ to 14′ 6″. Clay.

14′ 6″ to 22′. Gravel above and sand below: 1·06 grains per cubic yard.

Cut 6—

22′ 8″ to 34′ 4″. Fine gravel: ·268 grains per cubic yard.

During my visit I was able to ascertain the amount of gold obtained by a family of three Shans who were working the *shwe-myaung* at the foot of Pit 7. Gravel was laid along the tail race and washed for 1½ months by letting the water from the canal run over it. At intervals the workers cleaned out the pebbles by means of a basket sieve and the work was continued till the race was filled with the heavier part of the gravels only. Work was only carried on for three or four hours a day during seven days in the month. When the concentrates were cleaned out and panned, the gold was sold to traders in Maingkaing for Rs. 7 as. 12, which works out at about one anna a day per man over the whole 1½ months, and from 3 to 4 annas a day taking only the actual working days. The gold is separated by amalgamation, and the small residue of platinum, etc., is thrown away as valueless.

Teingon.

The gravels at Teingon are similar to those around Kyobin and form cliffs about 25′ high running approximately north and south and lying ½ mile back from the river.

There is one long canal known as the Hwe-latak[1] by which water is brought along the foot of the escarpment. Gold-washing is carried on at four points on this canal, and, during the rains only, at a fifth locality further inland.

Cuts were made in two of the cliffs at the localities marked on the map.

Cut 7—

This cut was in 15′ 10″ of gravel and 7′ of sand.

All was washed in one lot and gave 4·474 grains to the cubic yard.

Cut 8—

1′ to 15′ 6″. Gravel and sand: ·966 grains per cubic yard.

15′ 6″ to 24′. Gravel: 1·233 grains per cubic yard.

24′ to 32′. Fine gravel: 1·52 grains per cubic yard.

Mekkalek.

The *older gravels* are washed at Mekkalek and other localities in the neighbourhood.

Mr. J. M. Wright, who had visited these washings, informs me that they are very similar to those at Kyobin and Teingon.

I was unable to visit them myself, but do not think there is the least probability of their being any richer than those already described.

EXPLANATION OF PLATES.

Plate 23.—Sketch map of part of Chindwin River . . Scale 1 in. = 4 m.

Plate 24.—Fig. 1—Gold Workings at Kyobin and Teingon. Scale 6 in. = 1 m.

Fig. 2—Gravel Banks at Helaw and Gyogon . Scale 6 in. = 1 m.

Plate 25.—Record of pits around Kyobin.

[1] *latak* (Shan)—a small loach.

THE CORRELATION OF THE SIWALIKS WITH MAMMAL HORIZONS OF EUROPE. BY GUY E. PILGRIM, D.SC., F.G.S., *Officiating Superintendent, Geological Survey of India.* (With Plates 26 to 28.)

It had not been my intention to add anything to my "Preliminary Note on a Revised Classification of the Tertiary Freshwater Deposits of India"[1] until it should be possible for me, in an extended memoir, to deal with the whole subject in much greater detail. Since, however, it has been suggested by more than one of my critics that the mere list of the various Siwalik faunas, as enumerated in that paper, does not supply sufficient evidence for the correlation adopted, it seems advisable, in view of the importance of the matter, to elaborate this evidence somewhat without waiting longer.

It will considerably add to the comprehension of what follows, if the above quoted paper be read before going further. The European correlation there adopted for the various Tertiary Vertebrate faunas of India remains substantially unaltered, although it is necessary that the lower bone deposits of the Bugti Hills should be known as Gaj instead of Upper Nari. This change has been made on account of—

Gaj age of the Bugti bone beds.

(1) E. W. Vredenburg's conclusion, based on the evidence of the foraminifera, that the Upper Nari of Sind is in part stampian and the Gaj chiefly aquitanian reaching, in its uppermost portion into the burdigalian. The upper aquitanian age which I assigned to the vertebrate fauna is, therefore, inconsistent with a correlation with the Upper Nari, and the presence of an undetected unconformity between the bone beds and the marine band of Lower Nari age is, therefore, indicated;

(2) The identity, according to Vredenburg, of three species of *Ostrea*, found in association with the lower Bugti vertebrates, with species occurring in the Upper Gaj of Sind. This completes the evidence for the unconformity

[1] *Rec., Geol. Surv., Ind.*, XL, pp. 189—205 (1910).

suggested above and, further, renders it possible, that the lower Bugti bone beds should reach, at least in part, into the burdigalian.

Age of the Kuldanas.

With regard to the Kuldanas, which I correlated with the Bugti beds on the evidence of the fossils which I found at Fatehjang three years ago,[1] I think that the more advanced development of *Teleoceras fatehjangensis* Pilg. and the presence of a newer type of *Hemimeryx* suggest a slightly more recent age, so that the Kuldanas may very well be lower burdigalian. I do not, however, intend to deal further here either with this fauna or with the barren formation which directly succeeds it—the Murree, but only with the true Siwaliks which conformably overlie the Murrees.

Previous views on the Siwalik Faunas.

In all the publications of the Geological Survey previous to 1910, only two faunas had been recognized to exist in the Siwaliks :—

(*A*) That of Sind and Perim Island, erroneously made to include specimens of Gaj (upper aquitanian) age from the Bugti hills. This was rather doubtfully stated to be not older than Upper Miocene ;[2]

(*B*) that of the Salt Range, collected by W. Theobald, chiefly from the localities of Hasnot,[3] Jabi and Niki, which was united with that of the Siwalik Hills collected chiefly by the classic labours of Falconer and Cautley and also with that of Burma. This fauna was very generally regarded as Pliocene.[4]

Since Theobald broadly admitted the likelihood of some of the fossils brought to him by the native peasantry having come from lower horizons than the mass, it was open to writers like Lydekker, Schlosser and Stehlin to express a decided opinion that certain of the older types, included in set B, were Miocene and should be classed with set A. In 1910 I tried to make it clear that the deposits and fauna fell into three divisions, to which I gave the names Upper, Middle and Lower Siwaliks, all these divisions being represented faunistically in the Salt Range area succeeding

[1] Pilgrim. *op. cit.* pp. 187, 188.

[2] I shall show later on (p. 320) that the fauna of Perim Island is considerably newer than that of Sind and is probably the equivalent of that found at Nagri in a low horizon of the Middle Siwaliks.

[3] The name of the village Hasnot has been quoted by all previous writers as Asnot.

[4] *Manual of the Geology of India*, 2nd edition (1893), p. 363.

one another in stratigraphical sequence. I did not then attempt any more detailed classification but it has since become increasingly apparent that a further subdivision is advisable. The table in Plate 26 gives the complete classification, which I have decided to adopt, with the names proposed for the different zones, their typical localities, their most characteristic species and their correlation with the generally recognized European horizons. The measurements given for the thicknesses of the various zones in the Middle and Lower Siwaliks are based on the section of these beds displayed between the Soan river and the Salt Range plateau. The thicknesses of the Upper Siwalik zones are taken from the area between Jalalpur and Kotal Kund. For the sake of completeness the fluviatile deposits older than the Siwaliks are included in the classification.

Revised classification.

I do not intend here to discuss the stratigraphy in any great detail, but one or two points may be amplified with advantage to my argument. These fall under two heads :—

(1) stratigraphical relations between the Middle and Lower Siwaliks,

(2) stratigraphical relations between the Middle and Upper Siwaliks.

Stratigraphical Relations between the Middle and Lower Siwaliks.

Between the top of the Middle Siwaliks on the Soan river and the Salt Range plateau occurs an almost continuously descending series of river deposits. In places these are somewhat warped and there is a shallow syncline. The angle of dip varies, tending to steepen in the lower beds, but the sections which cut Chinji and run northward to Trap and Dhok Pathan, are singularly free from violent disturbance. It is one of these which is represented in Plate 28, fig. 2. From summit to base the dip never exceeds 10° and is frequently much less. The general direction of dip is NNW. The total thickness of the beds here included is about 10,000 feet. Of these the topmost 6,000 feet are Middle Siwalik, measuring down to the dividing line previously adopted, the zone of red nodular clays and concretionary pseudo-conglomerates free from pebbles. Since portions of the ground between Chinji and the Soan river are

Sections in the Salt Range.

covered by Post Tertiary deposit, which conceals the older rocks from view, the estimate of the thickness of the Middle Siwaliks in this area can be no more than an approximation to the truth. This cannot, however, be less than I have stated and may be greater should the syncline, mentioned above, prove shallower than I anticipate. At Hasnot, on the other hand, which lies in the eastern portion of the Salt Range area, the Middle Siwaliks are no more than 4,000 feet thick.

The most important fossiliferous horizon of the Middle Siwaliks occurs only some 500 feet from the top and includes the Dhok Pathan beds. It is this horizon which I correlate with that of Pikermi and Samos. Although fossils—chiefly *Hipparion*—are found occasionally throughout the series, we have to descend to a level of no more than 1,500 feet above the base of the Middle Siwaliks before we meet with the next important fossiliferous zone, that of Nagri, 10 miles east of Chinji. The fauna of this zone is discussed on page 318. The lowest 1,500 feet of the Middle Siwaliks is practically unfossiliferous. Then follows, but without any very abrupt break, the zone of bright red nodular clays and concretionary conglomerates with interbedded sandstone 2,300 feet thick. This is fossiliferous throughout, and may be divided into an Upper and a Lower Chinji zone. The former may be considered to extend through a thickness of 800 feet, in which *Hipparion* occurs, though rarely, with a large antelope, possibly *Palaeoryx sp.*, and a species of *Hyaena*. The few isolated teeth by which the Upper Chinji *Hipparion* is known appear to differ from those found in the Middle Siwaliks only by being slightly smaller and more brachyodont.

Both the genus *Hipparion* and the other forms mentioned above, are unknown in the lower 1,500 feet, which I may call the Lower Chinji zone.

Descending still lower the bright red clays cease, and with them all identifiable fossils, although there is a well-marked and very constant fossil wood zone. Some 1,700 feet of river sediment underlie the Lower Chinji zone, constituting the lowest division of the Siwaliks in the Salt Range. This is characterized by the same prevalence of concretionary pseudo-conglomerates, but they are rather different from those of the Chinji zone and are of two types, (1) a much softer and less calcareous kind, something like those of Sind and the Bugti hills and (2) a much harder, more compact and very calcareous kind like those that characterize the Nahan beds of the Sub-Himalayan zone. The clays are not as a rule nodular, and the bright red colour of the Chinij zone is absent. In the neighbourhood of the Indus the resemblance of the grey sandstones and concretionary conglomerates to those of Sind and the Bugti hills is still more striking. On the strength of this lithological resemblance, and because these beds form the base of the Siwaliks in the Salt Range, as the Lower Manchhars do in Sind and the Bugti hills, I have provisionally given to this lowest 1,700 feet the name of the Lower Manchhar zone. Seeing, however, that the fossils found at the base of the series in Sind and the Bugti hills are very distinct from those of the Lower Chinji zone, it would not be surprising if it should prove that these basal fossiliferous beds were laid down rather earlier than any in the Salt Range.

This same general succession of beds presenting the same lithological characters and fossil contents can be traced continuously between the Indus and the Jhelum.

Sections in the Sub-Himalayan area of Kangra and the Simla Hills

We will now pass to the Sub-Himalayan area and see how far a similar sequence can be detected. It is only within the last two years that it has become possible to attempt any exact correlation of the lower beds of this region with the Salt Range area. This has been both on account of the lack of any detailed stratigraphical work as well as the absence of any well-marked fossil fauna, or perhaps more truly through the failure adequately to combine the two. Throughout Kangra and in many places in the Simla Hill States there is found at the very summit of the thick mass of the Nahan sandstones, a constant zone of red calcareous nodular clays some 1,000 feet in thickness, which exactly reproduces in appearance the Chinji beds of the Salt Range, though occasionally containing a few pebbles. These beds pass gradually up into an immense thickness of pebbly sandstones with interbedded clays ending in a boulder conglomerate zone. If these red nodular beds had been unfossiliferous, I should unhesitatingly have classed them with the Upper Chinjis, merely on account of the lithological resemblance. They happen, however, to be fossiliferous in most of their outcrops, although the fossils are not numerous. It is noteworthy that *Hipparion* frequently occurs, and this frequency alone suggests that these beds are more recent than the Upper Chinjis, in which *Hipparion* is scarce. At Nurpur there was found also a large antelope apparently identical with a species found at Nagri in beds which overlie and are, therefore, younger than the Upper Chinjis, and perhaps ancestral to a Strepsicerine n. gen. sp. *latidens* Lyd., common at Hasnot. At the same time since the fauna also includes, as found in the Nurpur locality, *Amphicyon palaeindicus*, a Chinji species, it will be seen that Lower Siwalik affinites are not wanting. *Dinotherium, Giraffa, Dorcatherium* and a lower molar of a Merycopotamoid which is perhaps *Hemimeryx*, also occur.

The beds of the Kalawala Rau in the Siwalik hills to the north of Saharanpur have yielded a small fauna of similar type. Here, though red nodular clays are not found, the pisolitic pyritous beds are paralleled by similar beds at Nurpur. By their position at the top of the Nahan series they have already been the occasion of some discussion as to whether they were more appropriately placed in the Middle or Lower Siwaliks.[1]

A somewhat similar case has been found on the eastern side of the Chambal ridge, that is to say at the extreme eastern limit of the Salt Range area. Here the red calcareous clays of the Chinji zone occur, as usual, beneath the Middle Siwaliks. Sufficient evidence for the correlation of the latter is afforded by the presence of true pebble beds, associated with orange clays and grey sandstones, only some 40 feet above typical red Chinji clays. Immediately beneath the lowest of these pebble beds is a pisolitic ferruginous band, associated with a nodular clay, the lithological resemblance of which to the fossiliferous beds of Nurpur and the Kalawala Rau is noticeable. This band yielded *Hipparion* remains only. Remembering that *Hipparion* was rare in the Upper Chinjis, and in the absence of any characteristic species of the Chinji zone, it is as likely that this bed should have been deposited later than the Upper Chinjis of Chinji, as that it should be the absolute equivalent of the latter.

If we consider this Nurpur fauna as at all newer than that of the Upper Chinjis, it is clear that the peculiar conditions which gave rise to the red nodular clays and concretionary pseudo-conglomerates must have persisted longer in Kangra and elsewhere than in the Chinji area. Accordingly, we have the choice of two alternatives, (1) either the Nurpur beds are represented at Chinji by Middle Siwaliks and are practically the equivalent of the Nagri zone, or (2) there is a time-break between the Upper Chinjis and the Middle Siwaliks in the Chinji area which is represented in other places by the Nurpur beds, or perhaps only the upper portion of those beds, the lower portion being the equivalent of the Upper

[1] *Rec., Geol. Surv., Ind.*, XL, p. 193.

Chinjis of Chinji. I prefer the second alternative, because I do not wish to destroy the significance of such a well-marked line of demarcation between the Lower and Middle Siwaliks, as is provided for us by the existence of an easily recognized red concretionary zone at the top of the former.

In any case it is obvious that the Nurpur beds are in the nature of passage beds between the Lower and Middle Siwaliks. At present I shall class them with the Upper Chinjis, with a bias towards viewing them as in part slightly newer than the Upper Chinjis of the Chinji area.

Further evidence on this question is afforded by the interesting fossil find made by Sub-Assistant Vinayak Rao at Hari Talyangar in the Sub-Himalayan area referred to below (page 319). The beds, in which the fossils occur, are some 1,500 feet higher than the Nurpur beds of that locality and their fauna, although Middle Siwalik, represents a decidedly older type than that of Dhok Pathan, and may be correlated as nearly as possible with that of Nagri. The significance of a discovery which enables us to fix this horizon so exactly will be realized when it is remembered that the Nurpur series is underlain by a great thickness of Nahan sandstones, so that the correlation of these with that portion of the Lower Siwaliks below the Upper Chinjis is amply demonstrated. Whether the base of the Nahans (an uncertain line in practice because of the frequent shading of these beds into the Kasaulis) is still older than any beds found in Sind is a conjecture which at present lacks proof, but which the great thickness of the Nahans urges me to suggest tentatively.

Homogeneity of the Upper Tertiary Fauna of India.

A further important result of these recent finds is to at once dispel any doubt which there might ever have been as to the existence of a Middle Siwalik fauna in the Sub-Himalayan area of an entirely similar type to that of the Salt Range. We may thus assume that in Upper Tertiary times India was inhabited throughout the area covered by these ancient river deposits by a fairly homogeneous mammalian fauna. The inconstancy and even the almost entire thinning out of the Middle Siwaliks stage in certain parts of the area still remains as plausible a suggestion now as when I first made it, though we have only lithological evidence to go by.[1]

[1] *Rec., Geol. Surv., Ind.*, XL, p. 194.

Concretionary pseudo-conglomerates of the Lower Siwaliks.

Before leaving the Lower Siwaliks it is worth while to refer to one of their important lithological features, which seems to bear somewhat on the subject of this note. I have more than once mentioned the concretionary pseudo-conglomerates, which so universally characterize the Lower Siwaliks, whether in the Lower Manchhar zone of Sind, the Bugti hills and the Salt Range, the Chinji zone, or the Nahan series of Kangra and the Simla hills.

In the Middle Siwaliks concretionary beds of any kind occur but seldom, and where they do their appearance is entirely different from those of the Lower Siwaliks. The concretions are not so thickly massed and the general look of the bed is suggestive rather of an unmistakable concretionary structure than of a conglomerate. In the Upper Siwaliks any sort of concretionary bed is a still greater rarity. No one has ever done more than mention this structure and in seeking, myself, for its explanation, it has occurred to me as possible that it might possess an important significance, which will appear later.

The possible ways in which these concretionary pseudo-conglomerates might have originated arrange themselves under two heads :—

(1) formation beneath water, due to segregation of calcareous matter, implying thereby an origin contemporaneous with the deposition of the bed;

(2) formation subsequent to the deposition of the bed.

There seem to be several reasons against the first of these. To begin with, a subaqueous deposit is most unlikely. It is hardly possible that such widely spread and such thick deposits as those of the Siwaliks can have been formed otherwise than on vast flood plains. Further, no reason presents itself for such concretionary beds being so abundant in the Lower Siwaliks but vanishing almost entirely in the Middle and Upper Siwaliks, for if the deposit be subaqueous then the conditions requisite for calcareous segregation must be constantly present.

If they were formed subsequently to the deposition of the bed, we have the choice of two alternatives. One—their formation at any period subsequent not only to that particular concretionary band, but subsequent to perhaps thousands of feet of overlying strata, thus being in the nature of veins and pockets produced by infiltration. It seems, however, hardly possible that such products of infiltration should be densely crowded into comparatively thin bands, often succeeding one another very frequently, and should be so entirely absent from the intervening sandstones and clays. Moreover, the appearance of the concretionary pellets is not that of ordinary infiltrating action, while side by side with the structure we are discussing we find veins and strings of mineral matter, which are evidently the result of the passage of highly mineralized solutions through the rock, probably at a much later date.

The second alternative explanation—, namely that the entire concretionary structure of any particular band was produced in it before the deposition of the layers above it, seems to me the one which satisfies most of the facts. The only way in which this can have taken place would be if long periods of entire or almost entire cessation of flood alternated with periods during which floods were of constant, probably annual occurrence. During the periods of rest, large portions of land surface must have remained almost dry and have been subject to atmospheric forces, capillarity and evaporation, such as determine the formation of *kankar* in the plains of Bengal at the present day. The concretionary band, therefore, represents a soil layer which is of greater or lesser thickness, according to whether it has remained subject to atmospheric influences for a longer or shorter time. In fact it might be termed "quasi-lateritic" in origin. Very often the appearance of the concretionary layers is remarkably like that of an ordinary "laterite," the small ferruginous pellets which often occur causing certain bands to resemble the pisolitic varieties of "laterite." Since, however, it may be concluded that the layers of sediment left exposed during each of the periods of desiocation would vary in their lithological character, being sometimes sand and sometimes clay, we should expect the subsequent character of the concretionary band to vary also. This is in fact the case. The colour and material of the matrix is very different in different bands, although the nature of the concretionary action in general appears to have been the same.

It may seem that I have entered into this question at unnecessary length for a paper of this nature, but the importance to my subject of the conclusion to which I have arrived will now appear. If the above explanation is accepted it is obvious that the thicker and more frequent the bands of concretionary pseudo-conglomerate are, the longer must have been the duration of the periods of rest from sedimentation and so much the more frequently must they have occurred. We may in fact consider such a deposit as that of the Lower Siwaliks as one containing countless small unconformities. It will follow, therefore, in spite of the small thickness of the Lower Siwaliks, (some 4,000 feet only), that the time occupied from the beginning to the end of the sedimentation may have been considerable, and possibly much greater than that of the 6,000 feet of Middle Siwaliks or the 6,000 to 8,000 feet of the Upper Siwaliks. Thus it seems reasonable that if we admit the sufficiency of a single European stage for the deposition of the Middle Siwaliks, we should demand at least two stages for that of the Lower Siwaliks. I do not intend to press this suggestion unduly or unnecessarily, but it will be seen later how far the character of the various Lower Siwalik faunas lends it support.

Stratigraphical relations between the Middle and Upper Siwaliks.

It will be found that this section contains considerable additions to what I wrote in my "Preliminary Note" of 1910,[1] as well as a certain modification in detail. This is very largely due to my recent field-work in the country lying between the Bakrala ridge and the river Jhelum, as well as in the Siwalik hills. A reference to the geological map of part of this area contained in Plate 27 will enable the following description to be followed more readily.

Sections in the Salt Range.

Between Jalalpur and the Chambal ridge a continuous descending series of deposits occurs, in the following order going from newer to older beds, the dips varying from 25° to 70°. A section taken along this line and passing through the village of Malakpur and the Chambal ridge is represented in Plate 28 figs. 1 and 1*a*.

	Thickness in feet.	
Upper Siwaliks	1,000—2,000	Loosely compacted sands at Rasul, further to the north-east than Jalalpur. Boulder conglomerates with *Equus* and *Elephas hysudricus*.
	4,000	Friable brown sandstones with interbedded drab or pale brown clays and conglomerate bands.

[1] *Rec., Geol. Surv., Ind.*, XL. pp. 191—193.

	Thickness in feet.	
Middle Siwaliks .	1,300	. Deep orange and reddish brown clays with grey sandstones and occasionally true conglomerate bands.
Nurpur zone (?) .	20	. Red calcareous nodular clay with a pisolitic ferruginous band containing *Hipparion*.
Chinji zone . .	1,500	. Red concretionary beds and pseudo-conglomerates with fossil wood in its lower portion.
Lower Manchhar zone	1,000	. Sandstones and clays of a paler tint with concretionary bands and containing fossil wood.

The outcrop of the Upper Siwaliks is continued to Darapur, and the same beds reappear in the Pabbi hills across the Jhelum, The highest beds in the series are loosely compacted sands, seen on the banks of the river, particularly at Rasul, where they have yielded *Stegodon ganesa*. The Jhelum, therefore, runs in a synclinal trough. All these localities have proved fossiliferous, but for the most part only in the uppermost 2,000 feet or so. The fossils found include, as I mentioned in my " Preliminary Note "[1], the characteristic genera, *Equus*, *Bos*, *Elephas* (as the species *E. hysudricus*), *Camelus*, *Sivatherium*, and *Dicerorhinus platyrhinus*. The lower 4,000 feet at Jalalpur are unfossiliferous, and in the Pabbi hills have yielded no identifiable fossil but *Stegodon*. Their beds are, however, clearly distinguished from the Middle Siwaliks, by the softer, coarser nature of the sandstones, the brown tint of sandstones and clays alike and the greater frequency of pebble beds.

The base of the series is not seen in the Pabbi hills; we must therefore return to the Jalalpur section in order to become acquainted with the lower beds. The Upper Siwaliks pass down very abruptly into a succession of deep orange and red clays and grey sandstones which are, obviously, of an entirely different type to anything that occurs in the Upper Siwaliks. No identifiable fossil has been found in these, but immediately beneath them is a red nodular clay, with a peculiar pisolitic band containing *Hipparion*. I have already referred to this bed (page 269) and have given my reasons for regarding it as representing a passage zone between the Lower and Middle Siwaliks. Its lithological character prohibits its being regarded as Middle Siwalik, although at the same time there is nothing in the fossil evidence to prevent us

[1] *Rec., Geol. Surv., Ind.*, XL, p. 192.

correlating it with the Nurpur beds and regarding it as formed during a slightly later period of sedimentation than is represented in the Lower Siwaliks of Chinji itself. Moreover, it is obviously the highest bed of the Lower Siwalik in this section, since immediately above it occurs a true conglomerate quite unlike anything older than Middle Siwalik. Assuming, then, that the 1,300 feet of strata between this pisolitic bed and the brown sandstones of the Upper Siwaliks are Middle Siwalik, two points are noteworthy :—

(1) their thickness is very considerably less than that of the Middle Siwaliks of Dhok Pathan (6,000 feet) or even those of Hasnot (4,000 feet),

(2) the deeper colour of the clays is more like what one sees at the lower horizons of the Middle Siwalik, and very different to the pale red or reddish brown clays of the fossiliferous Dhok Pathan and Hasnot zone.

Taking these two points in conjunction with the abrupt passage into the Upper Siwaliks, it seems highly probable that the entire Dhok Pathan zone is missing, to say nothing of a considerable amount of beds still lower in the series. Obviously, therefore, there must be a strong unconformity at Jalalpur between Middle and Upper Siwaliks.

Now this series can be traced in perfect continuity, except for a small interval near Jalalpur, where intense faulting complicates the recognition of the various beds, right into the Hasnot area where the Middle Siwalik series is much more fully developed even if not quite complete. The strata form an elongate synclinal basin of which the centre lies about three-quarters of the distance from Hatar to Kotal Kund. At Hatar there is nothing in the relations between the Middle and Upper Siwaliks appreciably different from what was noticed at Jalalpur. The thickness of the Middle Siwaliks has, however, increased to 1,700 feet. The transition from the one series into the other is just as abrupt. A mandible of a large *Sus* related to a specimen which Lydekker provisionally referred to *Sus giganteus* was found in the basal bed of the Upper Siwaliks, and 3,000 feet above this occurred *Elephas planifrons*. From the upper beds came *Elephas hysudricus*, *Equus*, and *Cervus aff. duvaucelli*. At Kotal Kund the Middle Siwaliks increase still further in thickness, and higher beds of a paler tint gradually come in. These last contain fossils of a Dhok Pathan type not far below the base of the Upper Siwaliks at Kotal Kund. The red nodular clays at a much lower level are also fossiliferous at Kotal Kund and have yielded species characteristic of the Chinji zone. Most important, however, is the fact that the lower 1,500 feet of the Upper Siwaliks is strongly fossiliferous. *Sus aff. giganteus* and *Sus hysudricus*, *Hippohyus*, *Merycopotamus*, *Hemibos*, *Stegodon* and *Hipparion* occur. *Hippopotamus*, is very abundant. Above this level but not more than 2,000 feet above the base of the Upper Siwaliks *Elephas planifrons* was found.

Hasnot forms the centre of an extensive outcrop of slightly rolling beds of Middle Siwalik type—grey sandstones alternating with pale reddish-brown clays often slightly concretionary and occasional pebble beds. These to the south-west dip under the Upper Siwaliks of Kotal Kund and to the north-east under those of Tatrot, while on the side of the Tilla ridge they turn up sharply and rest on the Lower Siwaliks. Their total thickness between the Tatrot plateau and Tilla ridge is just under 4,000 feet. The fauna of the Dhok Pathan zone is found through a thickness of some 1,000 feet. Some 500 feet higher we encounter on the Tatrot plateau the same conglomerates, soft sandstones and clays, of a drab or pale brown colour, which were seen at Kotal Kund, quite distinct from the grey sandstones and reddish clays of the Middle Siwaliks. The fauna is identical with that of the Upper Siwaliks of Kotal Kund, with the addition of *Mastodon sivalensis*, and Bovine teeth. It is to be especially noted that these lower beds of the Upper Siwaliks, which I call the Tatrot zone do not contain *Equus* or *Elephas* either at Tatrot or Kotal Kund.

The basal Upper Siwalik conglomerate is extremely hard and forms a capping to a steep scarp with a dip slope of only 5°. As the Bhandar beds beneath are much softer, the plateau is cut into by an extensive network of stream beds and gullies. The conglomerate breaks off in large blocks and falls into the stream bed beneath. These blocks are carried by water far down the stream into the midst of the Middle Siwalik outcrop, and weather out in the course of years giving up their fossils to the industrious villager. Consequently the fossils collected by previous workers, notably Theobald, and labelled "Hasnot," do not represent, as I had previously thought, a pure homogeneous fauna with perhaps a few species from *older* beds but have a strong contamination of Upper Siwalik species. It is easier than would at first sight appear to separate the Upper Siwalik species, owing to the fact that the Bhandar beds forming the upper 500 feet of the Middle Siwaliks are generally unfossiliferous, while the distribution of the drainage is such that the fossils of the Tatrot zone never get carried down beyond the outcrop of the Bhandar beds. It is, therefore, impossible that the Tatrot fossils should ever get mixed with those of the Dhok Pathan zone, the fossil localities of which are remote from the stream beds which carry down the former.

We have seen that in passing from the Jalalpur area to that of Hasnot, a very considerable thickness of beds has been added to the Middle Siwaliks, so that the conformity is necessarily much diminished. As to the precise amount of the time-break still left between the two series, we cannot be certain in the absence of any fossils from the Bhandar beds. That there is a time-break is, however, rendered likely by the sudden change in the fauna between the Dhok Pathan and Tatrot zones, greater than can be accounted for by the 500 feet of Bhandar beds. Moreover, at Kakrala not far from Tatrot *Microbunodon silistrense* appears to have been found at the very top of the Middle Siwaliks, just beneath the basal Tatrot conglomerate. This evidence points to a greater unconformity than the actual lithological appearance of the beds at this place would lead one to imagine. On the other hand, there are in places distinct appearances of a gradual passage from one series into the other. Again, the character of the Tatrot fauna inclines us on the whole to assign to it a rather older age than Middle Pliocene, while the Dhok Pathan fauna can hardly be older than upper pontian. Hence, it is probable that in the Hasnot area the unconformity is small.

Some 25 miles to the east of the Chinji area and near the village of Bhaun, which is situated 6 miles north-east of Kala Kahar, the synclinal fold mentioned above (page 266) is deeper than it is north of Chinji, and above the Middle Siwaliks we get a replica of the Tatrot beds including, according to Sub-Assistant Vinayak Rao who discovered these beds, some 2,000 feet of brown grits and clays, which contain precisely the same fauna as seen at Tatrot and Kotal Kund. A section through the beds of this area, adapted from Vinayak Rao's diagrams and notes is represented in Plate 28, fig. 3.

Sections in the Sub-Himalayan area.

In the Sub-Himalayan region the Tatrot fauna undoubtedly occurs, as all the genera and species mentioned above are figured in the *Fauna Antiqua Sivalensis*. It is also certain that these characteristic genera and species have not been found by Sub-Assistant Vinayak Rao, in the highly fossiliferous sandstones and clays lying beneath the boulder conglomerate zone in the Pinjor portion of the Siwalik hills. The latter region constitutes what I have called the Pinjor zone, and fossils have been found through a vertical distance of some 3,000 feet in it, but do not include *Merycopotamus*, *Mastodon*, *Hippohyus*, or *Sus giganteus*. It seems, therefore, highly probable that these types of the Tatrot zone do not extend higher than the basal beds. Hence, we may reasonably infer that those of Falconer's Siwalik Hills species which are identical with those of the Tatrot zone, come from essentially the same horizon,—a much lower one than the bulk of the Siwalik Hills fossils, though the localities from which Falconer obtained them are unknown.

Whether the Tatrot beds represent actually the lowest beds of the Upper Siwaliks, or whether a still lower unfossiliferous zone exists in the Siwalik hills or Kangra, is again uncertain. Judging by the appearance of absolute conformity between Upper and Middle Siwaliks in the Kangra area, as well as by the greater thickness of the Upper Siwaliks, I incline to the opinion that the lowest beds of the Upper Siwaliks are met with in Kangra, these corresponding to the assumed break in deposit at Tatrot. These beds will in that case be Lower Pliocene, though not perhaps lowest Pliocene, the latter position being possibly filled by the Bhandar beds.

The Fauna of the Dhok Pathan Zone.

The richest of all the Siwalik faunas is that of the Middle Siwaliks of Dhok Pathan, Niki and Hasnot. Since a large number of the Dhok Pathan fossils were excavated from a single small spot, and since the fossils obtained from Nila, Mithrala and other places along the Soan river situated on the same fossiliferous outcrop, are free from any possible contamination with fossils either of an upper or of a lower zone, I adopt this as the type of the zone. At the same time, since the rich fauna of the Middle Siwaliks of Hasnot occurs at practically the same level and contains all the same species, I shall include with the Dhok Pathan fauna that of the Hasnot beds, even at the risk of possibly taking in one or two species belonging to the Tatrot zone by mistake. This fauna is also the most important of all, and on the age to which we assign it depends largely that of each one of the other faunas

I shall therefore consider at some length the evidence for correlating this horizon with that of Pikermi and Samos, which appears to me to be overwhelming.

I may first remark that as long ago as 1879 W. T. Blanford[1] noticed that many of the same generic types were common to the Punjab and Pikermi, and therefore was inclined to regard the two deposits as homotaxial. Since, however, there was no stratigraphical evidence available for separating the beds of the Siwalik hills from those of the Salt Range, the faunas of the two localities were united, and such genera as *Elephas*, *Equus*, *Bos* and *Camelus* were included with the Pikermi types, and the whole referred to the Pliocene. Later, when an Upper Miocene age came to be adopted for the Pikermi stage among a certain section of geologists, there seems to have arisen simultaneously a vague tendency to restrict the Siwalik fauna to the Pliocene, mainly, no doubt, because of the supposed presence of the more modern types mentioned above. The supposed *Helladotherium* of the Markanda (now *Indratherium majori*) had been previously shown by C. J Forsyth Major to belong to an entirely different genus from the Pikermi *Helladotherium duvernoyi*,[2] and with the collapse of this evidence any serious attempt to correlate any portion of this fauna with that of Pikermi disappeared among this school, and the entire series of beds now classed as Upper and Middle Siwaliks were accepted without question as Pliocene. It will be seen, then, that my correlation of the Dhok Pathan zone—the only one which contains the true Pikermi types—with the pontian of Europe is only a reversion to a view which was generally held twenty years ago.

For purposes of comparison I have in the table which occupies pages 280—287, set the lists of the Dhok Pathan and Chinji faunas side by side with those of Pikermi, Saint Gaudens and Grive Saint Alban to emphazize the fact that the difference between these two Indian faunas is no less than that which exists between the faunas of two successive European zones. The new species contained in the lists are those which I have established since writing my "Preliminary Note." They are briefly referred to in the sequel. It will also be seen that a ew species previously noted as present in the Middle Siwalik are now removed from that position. This is because my last season's work has shown an unsuspected contamination of the

[1] Manual of the Geology of India, 1st edition, p. 583.
[2] *Proc. Zool. Sec.*, 1891, pp. 323-326.

fauna of the real Dhok Pathan zone at Hasnot with Upper Siwalik species. The details of the discovery that a highly fossiliferous outcrop of the Upper Siwaliks is situated close to the village of Hasnot are more fully discussed on page 276 of this paper. Suffice it to say here that not all the species collected either by Theobald or Vinayak Rao and labelled "Hasnot" can be accepted as Middle Siwalik. I have now omitted from the Dhok Pathan fauna such species as I have unquestionable grounds for considering as belonging to the Tatrot zone. To the names of the species which I have not rediscovered, and which therefore might conceivably be Upper Siwalik, I have prefixed an asterisk. The species in our Indian deposits, which are nearly or quite identical with European species, I have italicized.

List of Mammalian species from the Upper and Middle Miocene of Europe and India.

Dhok Pathan Zone.	Pontian of Europe.	Lower Chinji Zone.	Sarmatian of Europe.	Tortonian of Europe.
	(?) Dryopithecus rhenanus.		Dryopithecus rhenanus.	
				Dryopithecus darwini.
		Dryopithecus indicus.		
			Dryopithecus fontani.	
			Pliopithecus antiquus.	Pliopithecus antiquus.
	Pliohylobates eppelsheimensis.			
* Palaeopithecus sivalensis.				
			Oreopithecus bambolii.	
Semnopithecus (?) hasnoti.				
	Mesopithecus pentelici.			
*Macacus sivalensis.				
		Dissopsalis carnifex.		
			Hyaenarctus laurillardi.	
*Hyaenarctus punjabiensis.	Hyaenarctus atticus.			

List of Mammalian species from the Upper and Middle Miocene of Europe and India—contd.

Dhok Pathan Zone.	Pontian of Europe.	Lower Chinji Zone.	Sarmatian of Europe.	Tortonian of Europe.
*Hyaenarctus palaeindicus.				
	Hyaenarctus arctoides.			
Indarctus salmontanus.				
				Ursavus primaevus.
			Ursavus brevirhinus.	
	Ursavus depereti.			
	Ursus böckhi.			
		Amphicyon cf. *giganteus.*		Amphicyon giganteus.
			Amphicyon major	Amphicyon major.
		Amphicyon palaeindicus.		
		Amphicyon chinjiensis.	Amphicyon steinheimensis.	
Amphicyon lydekkeri.				
			Pseudarctos bavaricus.	
			Dinocyon sp. .	Dinocyon thenardi.
				Hemicyon goriachensis.
	Simocyon diaphorus.			
		Haplogale sp. .		Haplogale mutatum.
				Proputorius sp.
				Mustela delphinensis.
				Mustela transitoria.
				Mustela filholi.
			Mustela larteti.	
			Mustela regia.	
	Mustela pentelici			
				Trochictis hydrocyon.
	Promephitis larteti.			
	Promeles palaeatticus.			

List of Mammalian species from the Upper and Middle Miocene of Europe and India—contd.

Dhok Pathan Zone.	Pontian of Europe.	Lower Chinji Zone.	Sarmatian of Europe	Tortonian of Europe.
*Mellivorodon palaeindicus.				
*Mellivora punjabiensis.				
Potamotherium (?) haenoti.				
				Potamotherium franconicum.
		Potamotherium (?) sp.		
Enhydriodon cf. sivalensis.				
			Enhydriodon campani.	
			Lutra lorteti .	Lutra lorteti.
	Lutra hessica. .			
Lutra bathygnathus				
				Progenetta incerta.
		Progenetta proava		Progenetta crassa.
				Viverra leptorhyncha.
				Viverra modica.
				Viverra steinheimensis.
				Herpestes crassus.]
				Herpestes filholi.
	Ictitherium orbignyi.			
Lepthyaena sivalensis	Ictitherium robustum.			
Palhyaena hipparionum.	Palhyaena hipparionum.			
Palhyaena indica.				
Lycyaena macrostoma.	Lycyaena chaeretis.			
	Hyaenictis graeca.			
Hyaena cf. eximia	Hyaena eximia.			
Hyaena gigantea .				
		Sivaelurus chinjiensis.		
		Sivaelurus (?) sivalensis.		

List of Mammalian species from the Upper and Middle Miocene of Europe and India—contd.

Dhok Pathan Zone.	Pontian of Europe.	Lower Chinji Zone.	Sarmatian of Europe.	Tortonian of Europe.
Paramachaerodus cf. schlosseri.	Paramachaerodus schlosseri.			
Paramachaerodus sp.				
*Aeluropsis annectens.				
		Machaerodus sp.		
			Machaerodus jourdani.	Machaerodus jourdani.
	Machaerodus aphanistus.			
Machaerodus sp. .				
				Pseudaelurus quadridentatus.
				Pseudaelurus transitorius.
				Pseudaelurus lorteti.
Felis sp. . .				
			Felis tetraodon .	Felis sitteli.
Felis sp. . .	Felis attica .			
Rhizomys sivalensis				
	Hystrix primigenia			
*Hystrix sivalensis .				
		Dinotherium sp. .	Dinotherium bavaricum.	Dinotherium levius.
Dinotherium indicum	Dinotherium giganteum.	Dinotherium pentapotamiae.		
		Tetrabelodon angustidens var.	Tetrabelodon angustidens.	Tetrabelodon angustidens.
		Tetrabelodon falconeri.		
Tetrabelodon corrugatus.	Tetrabelodon pentelici.			
		Tetrabelodon macrognathus.		
Tetrabelodon punjabiensis.	Tetrabelodon longirostris.			
Mastodon hasnoti.				
Mastodon latidens.				
Mastodon aff. latidens.				

List of Mammalian species from the Upper and Middle Miocene of Europe and India—contd.

Dhok Pathan Zone.	Pontian of Europe.	Lower Chinji Zone.	Sarmatian of Europe.	Tortonian of Europe.
Stegodon clifti.				
Stegodon bombifrons.				
Hipparion punjabiense.	Hipparion punjabiense.			
Hipparion theobaldi.				
	Hipparion gracile.			
Hipparion chisholmi.				
		Aceratherium sp. aff. tetradactylum.	Aceratherium tetradactylum.	Aceratherium tetradactylum.
Aceratherium lydekkeri.				
	Aceratherium incisivum.			
Aceratherium sp.				
			Teleoceras brachypus.	Teleoceras brachypus.
		Teleoceras sp.		
	Teleoceras goldfussi.			
Teleoceras sp.				
			Dicerorhinus steinheimensis.	Dicerorhinus sansaniensis.
	Dicerorhinus schleiermacheri.			
Rhinoceros aff. sivalensis.				
				Macrotherium grande.
Chalicotherium (?) sp.	Chalicotherium goldfussi.			
	Ancylotherium pentelici.			
		Phyllotillon sp.		
				Choerotherium pygmaeum.
			Choerotherium sansaniense.	
			Hyotherium sommeringii.	Hyotherium sommeringii.
		Hyotherium cf. sindiense		Hyotherium simorrense.

List of Mammalian species from the Upper and Middle Miocene of Europe and India—contd.

Dhok Pathan Zone.	Pontian of Europe.	Lower Chinji Zone.	Sarmatian of Europe.	Tortonian of Europe.
*Tetraconodon magnus.				
		Sus sp.	Sus choeroides.	
	Sus palaeochoerus.			
Sus punjabiensis.	Sus major.			
Potamochoerus (?) titan.				
Potamochoerus (?) sp.				
		Sanitherium schlagintweitii.		
Listriodon sp.		*Listriodon pentapotamiæ.*	Listriodon splendens	Listriodon splendens.
		Listriodon sp.		
Microbunodon silistrense.		Microbunodon silistrense.		
		Hemimeryx pusillus.		
Merycopotamus cf. dissimilis.				
Merycopotamus sp.				
Hippopotamus iravaticus.				
		Dorcabune sp.		
		Dorcabune anthracotherioides.	Dorcatherium crassum.	
	Dorcatherium jourdani.	Dorcatherium minus		Dorcatherium jourdani.
		Dorcatherium sp.	Dorcatherium peneckei.	
			Dorcatherium guntianum.	
Dorcatherium majus	Dorcatherium naui.	Dorcatherium majus.		
			Palæomeryx, 5 species.	
			Micromeryx flourensianus.	Micromeryx flourensianus.
				Dicrocerus elegans.
		Dicrocerus sp.	Dicrocerus furcatus.	
	Dicroceros pentelici,			
*Cervus (?) simplicidens.				

List of Mammalian species from the Upper and Middle Miocene of Europe and India—contd.

Dhok Pathan Zone.	Pontian of Europe.	Lower Chinji Zone.	Sarmatian of Europe.	Tortonian of Europe.
*Cervus (?) triplidens.				
	Capreolus matheroni.			
		Propalæomeryx sivalensis.		
		Giraffokeryx punjabiensis.		
	Helladotherium duvernoyi.			
Helladotherium grande.				
Vishnutherium iravaticum.				
	Palæotragus roueni.			
	Samotherium boissieri.			
	Alcicephalus neumeyri.			
Hydaspitherium birmanicum.				
Hydaspitherium megacephalum.				
Hydaspitherium magnum.				
Giraffa punjabiensis	Giraffa attica.	Giraffa sp.		
				Antelope (gen. ind.) sansaniensis.
				Antelope (gen. ind.) martiniana.
				Antelope (gen. ind.) clavatus.
			Antelope (gen. ind.) lunatus.	
			Antelope (gen. ind.) haplodon.	
			Antelope (gen. ind.) cristata.	Antelope (gen. ind.) cristata.
Tragocerus indicus .	Tragocerus amaltheus.			
Tragocerus sp. .	Tragocerus valenciennesi.			
	Pseudotragus capricornis.			
	Protoryx carolinæ.			

List] *of Mammalian species from the Upper and Middle Miocene of Europe and India*—concld.

Dhok Pathan Zone	Pontian of Europe	Lower Chinji Zone.	Sarmatian of Europe	Tortonian of Europe.
	Protoryx hentscheli			
		Protragocerus 2 sp		Protragocerus chantrei
			Protragocerus clavatus	
	Pachytragus crassicornis			
		Strepsicerine antelope n gen n sp		
	Palaeoreas lindermeyeri			
	Protragelaphus zitteli			
	Protragelaphus skouzesi			
	Prostrepsiceros woodwardi			
Strepsicerine antelope n gen latidens Lyd sp				
Boselaphus (?) lydekkeri				
	Tragoceras oryxoides			
			Palaeoryx (?) sp	
Palaeoryx sp	Palaeoryx pallasi			
	Palaeoryx majori			
	Palaeoryx stutzeli			
	Palaeoryx ingens			
			Antelope (gen. ind.) haupti	
	Prodamaliscus gracilidens			
	Criotherium argalioides			
			Gazella (?) gracillima	
		Gazella sp.		
Gazella sp . .	Gazella brevicornis			
	Gazella gaudryi			
	Gazella deperdita			
	Oioceros rothii			
Proleptobos birmanicus.				

Primates.

The primates of the Middle Siwalik throw no certain light on the question of the correlation. In the Pikermi stage we find the first European representatives of the true quadrupedal cynomorphs, or Macaques. We have no proof that the Pikermi *Mesopithecus pentelici* is more primitive than the two species described as *Semnopithecus asnoti* and *Macacus sivalensis*. The Pikermi species is very perfectly known, and were it not for the different proportion in length between its fore and hind limbs, would infallibly be referred to *Semnopithecus*, from which genus it cannot be distinguished by its cranial or dental characters. As the Indian species is known only by its teeth it would not be a matter for surprise if future finds should show that it is really *Mesopithecus*. On the other hand, the absence of ancestral types in the sarmatian and tortonian of Europe leads us to infer that the Macaques are emigrants, so that it is not surprising that we should find in the Upper Chinjis (or possibly the lower beds of the Middle Siwaliks, since the precise locality of the specimen referred to was not definitely fixed) a primitive monkey of small size which certainly seems as if it should be referred to this type.

An unbiassed examination of the original specimen convinces me of the soundness of E. Dubois' conclusion that the Middle Siwalik *Palaeopithecus sivalensis*, possesses characters so distinct from the modern Chimpanzee, as to prohibit its being placed in the same genus.[1] R. Lydekker's original differentiation is therefore justified. It is interesting to note that a still more primitive species of the same type has been found at Hari Talyangar, in the Bilaspur State, which, from its stratigraphical position and the associated species, can be referred as nearly as possible to the Nagri zone. This particular anthropomorphous type of ape has not yet been found fossil elsewhere than in India, but it should be noted as affording evidence of the antiquity of all the modern anthropoid types, that *Pliohylobates eppelsheimensis* is of pontian age, while *Pliopithecus antiquus*, is a widely spread tortonian species of Europe, closely allied to the living gibbon. The genus *Pliopithecus* is found at least as far back as the helvetian strata of Sansan, and according to L. Mayet in the burdigalian beds of the Sables de l' Orléanais.[2]

[1] Dubois, Ueber drie ausgestorbene Menschenaffen, *Neues Jahrb. f. Min.* I, (1897), p. 83.

[2] *Ann. Univ. Lyon.* Fasc. 24, (1908), p. 244.

Of the greatest importance for correlation is the occurrence at Hasnot of an animal whose lower dentition is indistinguishable from that of the widely spread *Palhyaena hiparionum*. The entire dentition of *Lepthyaena sivalensis* is now known to me through recent finds. It is hardly distinguishable generically from *Ictitherium*, the differences being in the nature of a transition into *Palhyaena*. This special type, intermediate between the Viverrids and the Hyaenids, becomes practically extinct with the close of the Pikermi period. It occurs in the lignites of Casino, considered by C. Depéret and H. F. Osborn as of Lower Pliocene age. It should, however, be remarked that the mandible provisionally referred by Lydekker to *Hyaena sivalensis*, possesses features which would render an identification with *Palhyaena* just as plausible. The Pikermi *Lycyaena chaeretis* is closely allied to the very common Dhok Pathan species *Lycyaena macrostoma*. Amongst the true Hyaenids, *Hyaena eximia* or a closely allied form has been found at Hasnot. On the other hand the Hyaenas of the type of *H. crocuta*, which appear in the Pliocene of Europe for the first time, are equally absent from the Middle Siwaliks, although their representatives exist in the Upper Siwaliks as *H. colvini* and *H. felina*. Another mandible from the Middle Siwaliks of Nila, may be referred to the Chinese species *H. gigantea*, of Pikermi age according to Schlosser and differing little from *H. eximia* except by its greater size.

Carnivora.

Amongst the Ursids, the genus *Hyaenarctus* is represented in the Dhok Pathan fauna by two species *H. punjabiensis* and H. *palaeindicus*. Of these *H. palaeindicus* is a peculiar form showing certain dog-like affinities which do not admit of a comparison with European species of *Hyaenarctus*, but suggest a specialized form of *Dinocyon*. In Europe the genus first appears in the sarmatian of Monte Bamboli as the species *H. laurillardi*. This species is known only by the mandible, which in its structure resembles *H. punjabiensis*. It is, however, very much smaller and obviously more primitive. *H. atticus* of Pikermi was also established on a mandible, which is moreover badly preserved, and contains but two molars. As far one can judge, it is allied to *H. punjabiensis*. *H. insignis* of Montpellier, though showing distinct points of resemblance to *H. punjabiensis*, is apparently a more advanced type. The upper teeth have been figured by P. Gervais.[1] H. G. Stehlin has

[1] Zool. et Pal. Franc. Pl. LXXXI, figs. 3-7.

described with some care the mandible of the same species and mentions features which look like later developments.[1] In addition there are the upper molars of Alcoy and the Red Crag which are more nearly related to *H. sivalensis* of the Upper Siwaliks.

The genus *Ursus* already exists in the Upper Miocene of Europe as the species *Ursus böckhi* from the Bohnerz. This form is derived from *Ursavus* of the stage of Simorre. *Ursus* has not, however, been found in the Middle Siwaliks but from Hasnot comes the maxilla of a bear containing m^1 and m^2, of which the latter possesses a distinct rounded talon. On account of this very remarkable character, combined with certain *Hyaenarctus*-like features I consider it worthy of generic distinction and propose for it the name of *Indarctus salmontanus.* This may very likely be derived from the *Ursavus* type. In structure it somewhat resembles the Malayan bear *Helarctos malayanus*, but is twice the size. The recent form may possibly be a degenerate descendant of the Middle Siwalik species. It is, however, worth mentioning that so far as one can gather from the very meagre account of the European species *Hyaenarctus arctoides* described by Depéret from the pontian of Montredon[2], it seems to be very closely allied to the Hasnot maxilla. The measurements of the latter are as follows :—

Length of m^2	35 mm.
Breadth of m^2	27 mm.
Approximate length of m^1 . . .	28 mm.
Approximate breadth of m^1 . . .	25·5 mm

I am not aware how far these conform to those of *Hyaenarctus arctoides*. It must also be borne in mind that the mandible figured by Lydekker in Pal. Ind. ser. 10 Vol. III, Pl. XXXI, figs. 2, 3, was only provisionally referred by him to the maxilla of *Hyaenarctus palaeindicus*, and there is quite a possibility that it belongs to the species now under consideration. If this is so, there is an even greater likelihood that these two species *Indarctus salmontanus* and *Hyaenarctus arctoides* are representatives of the same curious type.

The Mustelidae are represented both in the Pikermi and Dhok Pathan stage by genera which only differ slightly from recent genera, and by species which can only be referred to existing genera. The types found are, however, different in the two regions. Thus at Pikermi we have *Promeles* and *Promephitis*, and in the

[1] *Bull. Soc. Geol., France* (4) VII, (1907), p. 219.
[2] *Comptes Rendus Acad. Sci. Paris*, CXXI, (1895), p. 433.

Middle Siwaliks *Mellivorodon*; at Pikermi *Mustela* and at Hasnot *Mellivora*.

Coming to the Lutridae both *Lutra hessica* from the pontian of Eppelsheim and *Lutra bathygnathus* show affinities to recent types. In another species of otter found at Hasnot there is a very close approximation in structure to the type of *Potamotherium valetoni* of the Upper Oligocene and Lower Miocene. From Hasnot also comes the genus *Enhydriodon*, described by Falconer from an unknown locality in the Siwalik Hills—presumably Upper Siwalik—and from the sarmatian of Monte Bamboli.

The Felidae of the Middle Siwalik provide us with another important identity with a characteristic pontian species. There is a curious type, possibly seen in the rather poorly preserved mandible from Eppelsheim described by Kaup under the name of *Felis ogygia*, and certainly existing in *Machaerodus schlosseri* of Pikermi and *Machaerodus orientalis* from Maragha, and two species from the Dhok Pathan zone of Hasnot. M. Boule [1] in reviewing these extra-Indian ones has referred them all to the same genus and very justly remarks that the absence of a symphysial expansion and the comparatively short diastema clearly separate them from *Machaerodus*. He prefers to regard them as *Felis*. But it seems to me that the diastema is too long for any *Felis*, from which genus these species also differ by their square chin and the large upper canine possessing a ridge behind (seen only in the Maragha specimen). To meet the difficulty, I propose to unite all these under the new generic name of *Paramachaerodus*. In any case one of these species is almost, if not quite, identical with *Machaerodus schlosseri*.

This type appears in the pontian of Europe for the first time, and it certainly cannot be on the line of *Machaerodus*, and although a remote connection may be traced to *Aeluricits* it is more probably a migratory type. Now two other mandibles,[2] showing the same structure but in a more primitive condition, with a longer diastema and pm^2 present, exist in India, one described by Lydekker under the name of *Aelurictis sivalensis*, from an unknown horizon of the Salt Range, and another still more primitive from the Chinji zone. There is no denying that facts point to the existence in India previous to the pontian, of the forerunners of the

[1] *Bull. Soc. Geol. France,* (4) I (1901), p. 569.

[2] I provisionally assign these to the new genus *Sivaelurus* founded on a maxilla from Chinji (see page 314, footnote).

Paramachaerodus type. As soon as migration became possible from Asia into Europe the type passed over, and appears both at Maragha and Pikermi as a species in the identical stage of development with its Indian contemporary.

Felis occurs at Hasnot, but the specimens are not sufficiently well preserved to afford good specific determinations.

The only member of the Canidae found in the Middle Siwalik is *Amphicyon lydekkeri*, a large species but quite distinct from the Lower Siwalik species which are allied to the large European species of the burdigalian and helvetian. It should be remembered that *Amphicyon* does not persist into the pontian of Europe, the Canids being represented by *Simocyon* only.

Rodentia.

This order is but scantily represented in the Middle Siwalik. The only genera known are *Hystrix*, by a species not particularly closely allied to the Pikermi *Hystrix primigenia* and a *Rhizomys*. The existing genera of this order are, however, recorded as far back as the burdigalian.

Proboscidea.

The evidence afforded by this class of animal is really the most complete of any. The ancient genus *Dinotherium* makes its final appearance in the Middle Siwaliks of India as in the pontian of Europe, being in both stages of much rarer occurrence than in the earlier deposits. There is, however, no doubt that it is a Dhok Pathan genus as its discovery at Nila[1] has been confirmed by another find at a horizon considerably above that of Nagri.

The genus *Tetrabelodon* is known at Pikermi by the species *T. pentelici* and *T. longirostris*. In the Dhok Pathan zone its existence is clearly proved by the beautiful specimen of a mandible from Hasnot, which R. Lydekker figured with its extended symphysis under the name of *Mastodon pandionis*.[2] This species is an exceedingly common one in the Dhok Pathan zone, and I now have a complete knowledge of its dental structure. The type of *Tetrabelodon pandionis* is an upper first molar, of which the locality is not precisely known but which Lydekker considers with a fair show of probability to have come from Sind.[3] That the specimen is of very much greater age than anything in the Middle Siwaliks is indicated by its strong resemblance, though in a more advanced

[1] *Rec., Geol Surv., Ind.*, XL, p.
[2] *Pal. Ind.*, ser. 10, I, p. 213, pl. 34-36.
[3] This specimen is figured in *Falc. Pal. Mem.* I. Pl. XXXIV, figs. 6, 7, and *Pal. Ind.*, ser. 10, III, Pl. V, fig. 5.

stage of development to specimens obtained from the upper aquitanian of the Bugti Hills by C. Forster Cooper. Further, the first and second molars of the Dhok Pathan species differ in structure from the type of *T. pandionis*. It is necessary, therefore, that a new name should be given to the Dhok Pathan species and as the wrinkling of the enamel is a very striking feature I propose for it the name of *Tetrabelodon corrugatus*. This is a trilophodont mastodon, like *Tetrabelodon pentelici*, but the tetralophodont type seen at Pikermi in *Tetrabelodon longirostris* is also represented in the Dhok Pathan zone by a species which we may know by Lydekker's name of *T. punjabiensis*. That it had an elongated symphysis is certain, although it seems likely that only the males were provided with lower tusks. The affinity between *T. punjabiensis* and *T. longirostris* is very close.

Side by side with these two there occurs a type represented for the first time in Europe by *Mastodon arvernensis* of the lignites of Casino considered by Depéret as of lower Pliocene age. This is the species, which Lydekker has figured in Pal. Ind., ser. 10, Vol. I., Plate 44, under the name of *Mastodon sivalensis*. As Lydekker himself has pointed out, the Middle Siwalik species differs from Falconer's *M. sivalensis* of the Upper Siwaliks (1) by being tetralophodont instead of pentalophodont, (2) by having the alternation of the columns very slightly marked. I therefore propose that the Middle Siwalik species be known as *Mastodon hasnoti*. It is true that *Mastodon arvernensis* shows signs of a slight advance in development in the direction of *M. sivalensis*, in the rather more pronounced alternate arrangement of the main columns and in the smaller number of accessory columns. Moreover, as the symphysis of *Mastodon hasnoti* is at present incompletely known, we cannot be certain that it was not longer and more primitive than that of *M. arvernensis*. If this should turn out to be the case no further proof would then be necessary that *M. hasnoti* was earlier than, if not even the immediate ancestor of *M. arvernensis*. At the same time no cogent reason appears for *M. hasnoti* failing to reach Europe in the pontian. Still one might feel an equal degree of surprise at the non-migration of *Stegodon* to Europe until the Pleistocene, although it abounded in the Dhok Pathan beds as well as in later deposits.

This brings us to a line of development, which in all its earlier stages is entirely unknown in Europe. This is first found in the lower pontian deposits of Perim Island as *Mastodon cautleyi* of which the last upper molar figured by Lydekker in Pal. Ind. ser. 10, Vol. III. p. XV, fig. 6, is taken as the type. In the Perim beds as well as in the Middle Siwaliks is found a further advance on this type in the species *Mastodon latidens*, with an increased number of ridges. *Mastodon latidens* is really entitled to a subdivision into two, a large and a small species, of which the former is to be regarded as the direct descendant of *Mastodon cautleyi*. The last species of *Mastodon* which can be referred to this line is the tooth from Lehri, of which the horizon is uncertain but may be possibly Upper Siwalik, figured by Lydekker in Pal. Ind. ser. 10, Vol. I, Plate 39, as *M. latidens* but which is better recognized as a new species, owing to the almost entire absence of accessory columns, for which I propose the name *Mastodon stegodontoides*. So close is this to *Stegodon clifti* that it is hard to separate the two genera. It will be seen that *Mastodon stegodontoides* carries on none of its ridges more than the usual four columns while anterior ridges of *Stegodon clifti* carry nine or ten mammillae.

The true *Stegodon* type however, appears in India before the extinction of the *Mastodon cautleyi* type which gave rise to it. So we find the species *Stegodon clifti* and *Stegodon bombifrons* in the Dhok Pathan zone. From these originated by a perfectly natural continuation along the same developmental lines the genus *Elephas*, in some period later than the Middle Siwalik. There is absolutely no trace of *Elephas* either in the Middle Siwalik or in the Tatrot zone of the Upper Siwalik. It first appears as the species *Elephas planifrons* some 2,000 feet above the base of the Tatrot zone.

In Europe a most important find of the same species has been made by Dr. Gunther Schlesinger [1] in the Schotterberges north of Dobermannsdorf near Vienna. By an unquestionable correlation with the highly fossiliferous "Belvedereschotter" Dr. Schlesinger arrives at the conclusion that the strata exposed at Dobermannsdorf are of three ages, the lowest corresponding to a typical Pikermi fauna found in the Belvedereschotter, the next to a fauna of Middle Pliocene age similar to that of Montpellier, and the upper one to an Upper Pliocene fauna with *Elephas meridionalis*. He considers that the horizon at which *Elephas planifrons* was found cannot be later than Middle Pliocene,

[1] Schlesinger "Studien über die Stammesgeschichte der Proboscidier" *Jahrb. d. k. Geol. Reichs.* Vol. 62, pp. 87-182, Vienna (1912).

while it may even be earlier. Confirmation of this opinion comes from another quarter. Madame Marie Pavlow [1] has recorded the occurrence of *Elephas aff. planifrons* from Bessarabia, which probably is of lower Pliocene age.

Elephas is clearly a migratory type in Europe, showing no indication of its ancestry in earlier deposits. On the other hand, since the earlier stages of its evolution are to be clearly recognized in the *Mastodon cautleyi* and *Stegodon phyla* of India, it seems probable that it originated in that country. It is therefore *a priori* to be expected that it should be found fossil in India even earlier than in Europe. To be on the safe side let us take Dr. Schlesinger's latest age limit for his find and assume a Middle Pliocene age for the European horizon of *Elephas planifrons*. It is then obvious that its non-appearance in the Tatrot zone, supposing that the absence is a real one and not due to the imperfection of the fossil record, is an almost certain proof that this zone is lower Pliocene. Hence the Dhok Pathan zone, which is separated from the Tatrot zone not only by the Bhandar beds but also by a possible time break, cannot possibly be newer than upper Miocene which according to Depéret is the age of Pikermi. If, however, some subsequent discovery should bring to light a specimen of *Elephas planifrons* in the basal beds of the Upper Siwaliks, while at the same time the Middle Pliocene age of the same species in Europe should have been settled beyond dispute, it would then become necessary to modify somewhat the above conclusions. In that case it would be impossible to regard the Tatrot zone as much older than Middle Pliocene and the time occupied by the deposition of the Bhandar beds and the succeeding time-break would then represent the Lower Pliocene, while it might be considered reasonable to include even the Dhok Pathan period or at least a portion of it in the Lower Pliocene. It may be as well in this connection to point out that the German school of geologists including Dr. Schlesinger himself regard the Pikermi stage as Lower Pliocene and so immediately preceding the Montpellier beds and the zone of *Elephas-planifrons*. There would then be a good deal to say in favour of this view as opposed to that now held by Depéret and the French school.

Perissodactyla.

The most frequent and most characteristic genus of animals met with in the Dhok Pathan zone is *Hipparion*. There can be little doubt that it

[1] Marie Pavlow, Les elephants de la Russie, *Mem. Acad. Sci.* St. Petersburg (1910).

attained a maximum during this period. It is decidedly less frequent at the Nagri horizon and in the Perim Island beds, while in the Upper Chinji zone only two or three specimens have been met with (see page 267). In the Tatrot beds its numbers have become very sensibly diminished, and in the upper divisions of the Upper Siwalik (if its occurrence is even certain) it is at all events extremely rare. From these facts alone one would be induced without further evidence to correlate the Dhok Pathan fauna with the widely distributed one of Pikermi and Samos, where the presence of the genus *Hipparion* in very great abundance has earned for it the name of the "Hipparion fauna." For the following reasons the appearance of the genus earlier in India than in Europe need not furnish any argument against this conclusion. The genus appeared suddenly in Europe and the fauna which it dominates to such an exclusive and marked degree, was not heralded by one in which it occurs in lesser abundance, or more primitively constituted, such as might be expected when any particular form originates on the globe. It is absent not only from the fauna of Monte Bamboli but also from each one of the various deposits put on the Saint Gaudens horizon by Depéret and referred by him to the sarmatian. This feature at once stamps it as a migratory form and it is in fact well agreed that it came to Europe from Asia. It is extremely improbable that it originated in India, because none of the ancestral types have been found in that country. It is far more likely, as W. D. Matthew suggests, that we must look in Central or North-Eastern Asia for its origin. Thence it must have migrated, first, equally to India and North America, and subsequently to Europe as soon as the barrier which hindered quadrupeds from passing over, had been removed. Its occurrence, though in smaller numbers, in India prior to Pikermi times would thus be explained. Considering the comparative isolation of India both from China and Persia even in Upper Miocene times, as evidenced by the respective faunas of the three countries, one can hardly imagine that the genus *Hipparion* reached India before it reached North America. It is, therefore, suggested that possibly the Ogalalla, Clarendon and Madison valley horizons, in which *Hipparion* occurs for the first time in North America, should be correlated not with the Pikermi stage, according to Osborn's and Matthew's present views, but with an earlier zone equivalent to that of the Upper Chinjis of India and of uppermost sarmatian age.

Hipparion is represented in the Middle Siwaliks by three species, *H. theobaldi*, *H. punjabiense*, and *H. chisholmi*. In the pontian of Europe all species of *Hipparion* have hitherto been referred to the Pikermi species *H. gracile.* The type of this is clearly distinct from either of the Indian species. Lately, however, by the kindness of Dr. A. Smith Woodward, I have been enabled to examine a very large collection of *Hipparion* skulls of all ages made by him at Pikermi. I have found undoubted proof of the existence amongst them of at least two species. One of these agrees perfectly with Gaudry's type of *Hipparion gracile,* while the other does not present any very clear points of difference from *Hipparion punjabiense.* The shape, size and position of the facial cavity is the same in the two species; the 2nd milk molar shows in both the peculiar feature of a metacone isolated from the hypocone and of a reentrant fold of enamel in the antero-external angle while the permanent teeth are indistinguishable. It cannot be denied that this identity goes far to confirm the correlation of the Dhok Pathan and Pikermi horizons.

Rhinocerotid remains occur in moderate abundance throughout the Siwaliks but generally as scattered and disjointed fragments. To work these out completely and determine the different lines of evolution and the species which represent the different evolutionary stages of each one of these lines, requires much more careful and prolonged study than it has at present been possible to give. It is, therefore, correspondingly difficult to arrive at any conclusions which are of value for correlating the deposits. The most frequent and characteristic Rhinoceros of the Dhok Pathan zone is the large species, of which a fine cranium was figured by Lydekker[1] under the name of *Aceratherium perimense,* but which seems separable from Falconer's type from Perim Island; I have thought it better to give the former the name of *Aceratherium lydekkeri.*[2] The latter is apparently met with in Burma as well as in the Salt Range. Neither of them can be compared with the Pikermi *Aceratherium incisivum,* though the premolars of the former are certainly more primitive than those of the European species. In the Chinji beds a much smaller species is found, which is very nearly allied to *Aceratherium tetradactylum* of the tortonian and sarmatian of Europe, and which may be ancestral to both *A. perimense* and *A. lydekkeri.*

[1] *Pal. Ind.,* ser. 10., Vol. II, Plates I, II.

[2] *Rec., Geol. Surv., Ind.,* XL (1910), p. 65.

The line of the true *Rhinoceros* represented in the Upper Siwaliks by *R. sivalensis* seems to have been in existence in Dhok Pathan times.

Ancylopoda.

Although animals belonging to this order lived in India at this period their remains are too fragmentary to say whether they should be regarded as ancestral to the Upper Siwalik *Chalicotherium sivalense*, or should rather be referred to the genus *Phyllotillon*, of which representatives are found in the Lower Chinjis, or whether they belong to *Ancylotherium*, the Pikermi genus, about which as little is known.

Anthracotheriidae.

This family became extinct in Europe in the burdigalian. No significance must, however, be attached to the fact that a tetraselenodont type persisted in the Lower Chinjis in the genus *Hemimeryx*, leading to the highly specialized *Merycopotamus*, which we find in the Tatrot zone of the Upper Siwaliks as a species which cannot be distinguished from the Middle Siwalik form.

Nor even is it any proof of the antiquity of the deposit that the genus *Microbunodon*, is found as the same species *M. silistrense* from the Lower Manchhar zone right up to the top of the Middle Siwaliks, in a form differing but little from the last European representative. Such survivals in one particular part of the world of ancient types, which have become extinct elsewhere, can be paralleled by many other instances.

Suidae.

The work at present done on the Suidae of the Siwaliks is insufficient to afford a satisfactory basis for classification. The difficulty of such work is enhanced by the fragmentary nature of the material. A good example of the results, which such specimens are apt to bring forth, is shown by the designation *Sus hysudricus* under which have been placed pigs of every degree of size and development occurring from the Lower Manchhars of Sind up to the Boulder conglomerate zone of the Siwalik Hills. H. G. Stehlin has recognized amongst these two distinct lines, the one referable to *Potamochoerus* and the other to the true *Sus* and I have no doubt that there are several others of greater or less importance.

A gradual transition can be traced from the *Sus* of the Chinji beds which has a short last molar and large anterior molars, approximating to the type of *Hyotherium sommeringii*, through the Middle Siwalik forms, where the increase in length of the last molar is clearly to be seen, representing a stage comparable with *Sus palaeochoerus* of Eppelsheim, until we reach the Tatrot zone where we are introduced to a more modern type in which the last molar has increased in length out of all proportion to the anterior molars.[1] The *Potamochoerus* line seems not to have reached Europe until much later than it makes its appearance in India, when it is found as the species *Potamochoerus provincialis* in the Middle Pliocene of Montpellier. *Potamochoerus giganteus* of the Upper Siwaliks of India represents the limit of size attained by the direct line. The mandible referred by Lydekker to *Sus giganteus* belongs to a line in which the premolars have enlarged in the same way but to a much less degree than in *Tetraconodon.* This specimen probably came from the Dhok Pathan beds of Hasnot, but the type is represented at the very base of the Tatrot zone by a mandible in which the enlargement of the premolars is even greater.

The large *Sus titan* has been referred by H. G. Stehlin to *Potamochoerus*, but it is at any rate not on the direct line. Although it is in no way related to *Sus major*, the large pig of Pikermi and Eppelsheim, yet it is worth noting that these gigantic pigs make their appearance for the first time in the Dhok Pathan zone as they do in the pontian of Europe. Smaller species allied to *Sus titan* occur both in the Dhok Pathan beds as well as in earlier deposits. An altogether smaller species of pig occurs in the Dhok Pathan zone, described as *Sus punjabiensis*, which may be an ancestral form of *Hippohyus*. *Sanitherium schlagintweitii* is a species of which the exact horizon is unknown.

The genus *Listriodon* has not been found either at Dhok Pathan itself or at Hasnot. Specimens were, however, recorded from Niki by Theobald and a specimen brought to me when I was encamped at Hasnot seems not to have come from a very low horizon, though perhaps rather lower than the Dhok Pathan zone. On the whole, we must conclude that *Listriodon* should be included in the Dhok Pathan fauna, but that it was very scarce. As it died out in the tortonian of Europe its persistence in India is noteworthy.

The genus *Hyotherium* is absent from the Dhok Pathan fauna. The species *Hyotherium cf. sindiense* of the Chinji beds has, however,

[1] It should be noted that the mandibles figured by Lydekker in Pal. Ind., ser. 10, Vol. III, Plate VIII, figs. 2, 3 belong, if we may judge from the nature of the matrix, to the Tatrot zone.

left a descendant in which the enlargement of the premolars, so characteristic of that species of *Hyotherium*, has proceeded to an excessive degree. This is the remarkable species described by Lydekker under the name *Tetraconodon magnus*, though it is more than doubtful whether it belongs to the same type as Falconer's species from the Siwalik Hills, now known to us only by a woodcut in the Palaeontological Memoirs. Interesting intermediate types have been found in *Tetraconodon minor* from Burma,[1] and *Hyotherium indicum* Lyd. sp.[2] from the Nagri horizon.

Hippopotamidae.

Although the genus *Hippopotamus* is decidedly rare at the Dhok Pathan horizon, in very striking contrast to its abundance in the Tatrot beds, yet there seems to be undoubted evidence that it does occur. The species *H. iravaticus* occurs in Burma, where it is said to be associated with fossils of a Middle Siwalik type at the very base of the Irawaddy series and the same species seems to have been found in the Hasnot beds, while teeth of the genus come from Dhok Pathan itself.

The earliest record of the genus in Europe is from the lignites of Casino[3] referred by C. Depéret to the Lower Pliocene and apparently slightly newer than Pikermi though regarded by some geologists as part of the pontian. C. W. Andrews has discovered an allied species, which he has provisionally referred to *H. hipponensis* Gaudry, in the Wadi Natrun in Egypt[4] associated with a fauna which at all events points to an age no later than that of the Casino lignites. It should be noted that the type of this species was described by A. Gaudry[5] from the Pliocene or early Pleistocene of Algeria. Its appearance in India earlier than in Europe is not, however, discordant with probability for the following reasons. The origin of the genus is very obscure. There is, however, some reason to suppose it to be a specialized branch of a Merycopotamoid line and there is no doubt that it shows certain features in common with *Merycopotamus* which favour this view. Now, nowhere else in the world among known fossil localities of Miocene age do the Anthracotheriidae and in particular the Merycopotamoid line of the family, present such a varied type of development as in India.

[1] *Rec., Geol. Surv., Ind.*, XL, p. 67.
[2] *Pal. Ind.*, ser. 10, II, p. 349; *Rec., Geol. Surv., Ind.*, XL, p. 190 footnote; *infra*. p. 319.
[3] Pantanelli *Mem. R. Accad. Lincei*, (3), Vol. III, p. 309 (1879).
[4] *Geol. Mag.* (4), vol. IX, (1902), p. 434.
[5] *Bull. Soc. Géol. France* (3), vol. IV, (1876) p. 501.

It is therefore reasonable to place the centre of dispersal of the group, not necessarily in India, but at all events in some region not very remote therefrom, probably in the direction of Africa, possibly in central Africa itself. In the Miocene deposits of such a region should one search for the origin of the genus *Hippopotamus*, and an earnest of the success likely to attend such a search is the occurrence of a fully developed representative of the type in pontian strata of the Middle Siwalik. The recent discovery of a species of *Merycopotamus* in the pontian of Tunis[1] does not militate against this view, as the Merycopotamoid type is of ancient origin, witness the occurrence of the species *Hemimeryx affinis* in the upper aquitanian beds of the Bugti hills, and *Merycopotamus africanus* may easily have been an emigrant from the South or East.

It is of interest to recall the record by M. Schlosser of *Hippopotamus* in supposed association with a "Hipparion fauna" of Pikermi age in China.[2]

Giraffidae.

The Giraffidae afford one of the most striking instances of the sudden appearance of a group in the pontian of Europe, which had been quite unknown there previously. The distribution of the group points with some degree of probability to its arrival by way of Asia. Its history in India gives us one of our most complete proofs for the pontian age of the Dhok Pathan zone. There we find side by side with *Giraffa punjabiensis*, paralleled by *Giraffa attica* at Pikermi, the large genus *Helladotherium* allied to the Pikermi species *H. duvernoyi* and the almost equally large *Vishnutherium*. The Palaeotragine group, including the genera *Palaeotragus*, *Samotherium* and *Alcicephalus* has not so far been recognized in India. This may, however, be due to the scantiness of the material so far found. On the other hand, allied forms possessing a complex horn development occur in the genus *Hydaspitherium* in the Dhok Pathan zone and as *Bramatherium* in the rather older Perim Island beds. As we should expect if the strata below the Dhok Pathan zone were older than Pikermi age, we find ancestral Giraffine types even in the lower beds of the Middle Siwaliks in the shape of a small Helladotherine, perhaps referable to the genus *Giraffokeryx*, in the Nagri beds, and a small species

[1] M. Boule. Sur quelques Vertébrés fossils du sud de la Tunisie, *C. R. d. Acad. Sci, Paris.*, CL, (1910) p. 812.
[2] *Abh. d. k. B. Akad. Wiss., München*, XXII, p. 95, (1906).

of *Giraffa* in beds of similar age at Hari Talyangar. From the latter locality comes a large Giraffoid mandible in which a curious feature is the bilobate character of the last column of the last lower molar. In the Chinji zone the primitive character of the Giraffine type is evident in the genus *Giraffokeryx*, which is on the line of *Helladotherium* and in *Propalaeomeryx* (described under the name of *Progiraffa*).

Bovidae.

Amongst the antelopes which frequented the plains of Europe in pontian times it is agreed that the *Tragocerinae* were preceded in the Middle Miocene of Europe by ancestral forms. M. Schlosser[1] regards *Antilope clavata* of Sansan as the ancestor of *Tragoceros*, *Pseudotragus* and possibly *Protoryx* and *Protragoceros chantrei* of La Grive Saint Alban as having given rise to *Pachytragus*. Schlosser[2] also doubtfully refers an antelope with large teeth from the supposed sarmatian of Casteani to the genus *Palaeoryx*, while he suggests[3] that *Antilope haupti* from the same locality and another from the pontian of the Swabian Bohnerz, both with exceedingly hypsodont teeth may be related to the pontian Chinese genus *Paraboselaphus*. *Antilope gracillima* from the supposed sarmatian of Monte Bamboli is also very hypsodont, and Schlosser suggests[4] that by its small size it may be related to the Gazelles.

The widely spread and characteristic pontian genus *Tragocerus* (not found in beds of a later age in Europe) is plentifully found in the Dhok Pathan horizon of the Middle Siwaliks, the most common species being almost identical with the Pikermi *Tragocerus amaltheus*. That it is not a later survival in India is proved by the fact that in the Chinji zone the same type of antelope abounds, but possessing much more primitive characters and very closely allied to the helvetian *Antilope clavata* and the tortonian *Protragocerus chantrei*. Notwithstanding the sarmatian forms doubtfully considered by Schlosser to show relationship to the genera *Palaeoryx*, *Gazella* and *Paraboselaphus*, it will be freely conceded that one of the most striking features of the pontian is the sudden appearance of large numbers of antelopes of a decidedly modern type now confined to Africa. Such are *Prodamaliscus*

[1] M. Schlosser, Die fossilen Cavicornia von Samos, *Beitr. Pal. Geol. Ost. Ung.*, XVII, p. 94 (1909).
[2] *Ibid*, p. 78.
[3] *Ibid*, pp. 79, 80.
[4] *Ibid*, p. 79.

(*Bubalidinae*); *Palaeoryx* and *Tragoreas* (*Hippotraginae*); *Protragelaphus* and *Palaeoreas* (Tragelaphinae); *Gazella* (Antilopinae).

It is perfectly certain that these are migratory forms from Africa or Asia or from both. The fact that the pontian fauna of Persia and China is more nearly allied to that of Europe than to that of India seems to indicate that the line of migration was not from Africa through India to China, but from China equally to India and Europe, India being possibly even then a somewhat isolated area. The discovery by J. C. Merriam[1] of Strepsicerine antelopes in the Lower Pliocene of North America points in the same direction. In any case it is certain that India must have been in connection with their original centre of dispersal. It is also probable that their arrival into Europe took place for the most part, even if not entirely so, in the pontian.

Let us see now how far the history of the group in India affords evidence for the correlation of the deposits. Unfortunately large antelopine teeth though very abundant in the Dhok Pathan zone are generally solitary and association of molars and premolars or of teeth and skulls or horn cores occurs but seldom. The tragelaphine group is, however, represented by the species described by Lydekker as *Taurotragus* (*Oreas*) *latidens*, a large form having horn cores with a slight spiral twist. Its stage of development corresponds to that of the pontian *Tragelaphinae*, but it cannot be referred to any hitherto described genus. An ancestral form to this species and possibly to *Protragelaphus* and *Palaeoreas* is found in the Chinji beds.

The genus *Palaeoryx* seems to occur in the Dhok Pathan zone, found also as a smaller species in the Upper Chinji zone.

Lydekker, again, has described a species from Perim Island under the name of *Strepsiceros falconeri*.[2] Perhaps under the impression that many of the special features of this skull were due to crushing and deformation after death, he was led to refer it to the recent genus. A careful examination of the specimen has, however, convinced me that the peculiar flattening of the frontals is natural. This character united with the absence of a lacuna between the lachrymal and the frontal, the rugose structure of the enamel of the teeth and the presence of a strong intercolumnar tubercle, are against any very close relationship to *Strepsiceros*. In

[1] *Univ. Cal. Publ. Bull. Dep. Geol.*, V, No. 22 (1909), pp. 319—330.
[2] *Pal. Ind.*, ser. 10, IV, p. 8.

some respects it seems to approach *Boselaphus*, and may be the ancestral form of the Dhok Pathan species, of which Lydekker figured the teeth under the name of *Boselaphus sp.* and which the present writer referred to as *Boselaphus lydekkeri*.[1] I am now of the opinion that these teeth cannot belong to the genus *Boselaphus*, though they may be ancestral to it, and as I cannot assign them to any other genus, it will be necessary to establish a fresh one.

The genus *Gazella* is found in the Dhok Pathan zone and is represented by a smaller species in the Chinjis.

Thus it will be seen that the presence of large antelopes of a modern type in the Dhok Pathan zone, which are preceded by species in lower zones which may be regarded as ancestral to them, and are in some cases decidedly more primitively constituted than those of Pikermi and Samos, indicates that the Dhok Pathan species are of pontian age.

As compared to the pontian of Europe a rather modern look is given to the Dhok Pathan zone by the supposed presence of an ancestral form of *Leptobos*. This specimen is labelled "Ava" and it seems probable that it belongs to the Middle Siwalik of Burma.[2] Even should this be found correct, it is no matter for surprise that a species of the most primitive of the oxen which shows features still more akin to the antelopes than the Upper Siwalik *Leptobos falconeri* should appear as early as the pontian outside of Europe. I venture to name the specimen *Proleptobos birmanicus*.

Summary of arguments in favour of a pontian age for the Dhok Pathan zone.

To sum up the arguments contained in the preceding 17 pages, the pontian fauna of Europe is recognized to consist of three parts :—

(1) The indigenous types, of which ancestral forms are to be found in the sarmatian and tortonian of Europe.

(2) A migratory type which has reached Europe by way of Africa.

(3) A migratory type which has reached Europe by way of Asia.

1 *Rec., Geol. Surv., Ind.*, XL, p. 70.

2 The specimen was formerly contained amongst the collections of the Geological Society and is now in the possession of the British Museum. *Cf. Rec., Geol. Surv., Ind.*, XLIII, p. 14.

It is the last two types which impart to the pontian fauna the peculiar facies which distinguishes it wherever found. The African migrants, chiefly Hyracoids, the dicerine Rhinoceroses, and possibly some of the Bovine antelopes do not concern us here. But it is to the Asiatic migrants that one would expect to find close resemblances in a fauna of corresponding age in India. Moreover, in the fauna immediately preceding an Indian fauna of pontian age we should expect to find the forerunners of such types. The *Giraffidae*, *Hipparion*, several groups of Bovine antelopes, the *Hyaenidae*, *Paramachaerodus* exemplify the application of this argument. All these forms are represented by closely allied species in the Dhok Pathan zone of India, and by ancestral species or at all events forerunners in the Chinji beds, thus proving that the Dhok Pathan zone is equivalent to Pikermi.

In the first class of indigenous types one would not expect to find such close resemblances I assume such types to have been produced by independent evolution in both countries, from some common though more remote ancestor. We might, however, expect to find that the same stage of development had been attained simultaneously in both countries. This we find to be the case in the *Proboscidea*, *Palhyaena* and *Ictitherium* and *Tragocerus*, if with Depéret we regard the last three of these as indigenous types in Europe, but the fact that identical species occur in both regions, seems to show that migration of these particular species must have taken place from one of the two countries, in pontian times.

In the Dhok Pathan zone there exists yet another category. This includes animals which have not been found in the pontian of Europe, though in some cases they entered Europe in Pliocene times, as for example the *Hippopotamus*, the Potamochoerine or African river hogs, and ancestral oxen, (of which an extremely primitive and antelopine form of *Leptobos* probably occurs in the Middle Siwaliks of Burma) or even in the Pleistocene as in the case of *Stegodon*[1]. In other cases such forms seem never to have entered Europe, witness the true Asiatic *Rhinoceros*, and *Merycopotamus*. The reverse of this is seen in the case of the Dicerorhine Rhinoceroses, which existed in Europe from the burdigalian but do not appear in India until the Upper Pliocene as the species

[1] A. Smith Woodward, Description of the Piltdown skull, etc., *Quart. Journ. Geol. Soc. Lond.* LXIX (1913), p 139.

Dicerorhinus platyrhinus, to be continued into recent times as the Sumatran two-horned Rhinoceros. The dicerine Rhinoceroses also entered Europe in the pontian, but at no time penetrated to India. These facts carry with them the reply to any argument that should place the Dhok Pathan zone later than Pikermi, on the ground of the occurrence in it of *Hippopotamus*, primitive oxen, and *Stegodon*.

Finally, the discoveries which have enabled us to correlate the Pinjor horizon of *Elephas planifrons* in India with the Middle Pliocene horizon of *Elephas planifrons*, in Europe (see pp. 294-295) impel us to regard the Tatrot zone as Lower Pliocene, and the Dhok Pathan zone as Upper Miocene. Since no geologist has ever regarded the Pikermi beds as older than Upper Miocene, this practically confirms the equivalence of the Dhok Pathan zone and the Pikermi stage.

Pikermi Stage consequently Upper Miocene.

Provided nothing should in the future disprove the premises on which the preceding argument is founded, it also follows that we shall have entirely established Depéret's attribution of the Pikermi horizon to the Upper Miocene in opposition to the authors who regard it as Lower Pliocene. A lower Pliocene age for Pikermi could only be maintained in the face of the correlation of the *Elephas planifrons* horizon if it could be shown that the Dhok Pathan zone were older than Pikermi. But although it might conceivably be contended on internal faunal evidence that the Dhok Pathan zone is younger than Pikermi, the reverse is hardly imaginable, when we consider how far beneath it the genus *Hipparion* first appears and how little different the *Hipparion* of Perim Island and the Upper Chinjis is from that of Dhok Pathan. Further, the slight distinction between *Mastodon hasnoti* and *Mastodon arvernensis*, and the existence of the same developmental stages in various lines both at Pikermi and Dhok Pathan strongly militate against any such possibility. The apparent passage of beds with a Pikermi fauna into beds with a fauna of Montpellier, universally accepted as Middle Pliocene, which is recorded at Belvedere and other places in Austria may therefore be illusory, and an undetected time break or at all events a period when deposition was extremely slow, may be present between these two faunas.

Whereas Depéret does not differentiate between the various faunas of pontian age, but tacitly regards them all as equivalent to Pikermi, it will be seen that I call the Dhok Pathan zone upper pontian. I do so mainly because the earliest *Hipparion* are not so much more primitive than the Dhok Pathan forms as to justify me in regarding them as contemporaneous witn the older sarmatian. It will be seen when I come to consider the fauna of the Lower Chinji beds that, on the whole, the facies of this fauna is hardly older than the Saint Gaudens stage. The earliest position to which I should be at all inclined to assign it, would be one intermediate between the stages of Simorre and Saint Gaudens. It may well be that the pontian fauna which in India is easily divisible into two (1) that of Dhok Pathan and (2) that of Nagri, is in Europe indivisible. Hence the numerous localities containing the species of the "Hipparion fauna" may some of them be lower pontian and contemporaneous with the Nagri zone, and others upper pontian and contemporaneous with the Dhok Pathan zone. It must be understood that I make no pretence to assign Pikermi to the upper rather than to the lower pontian or to point out which of the localities are newer than the rest. In India the occurrence of different fossil zones in stratigraphical continuity enables us to combine the geological with the palaeontological evidence in a way that is perhaps impossible in Europe. If for instance we had no knowledge of the fact that the Nagri fauna occurred some 3,000 feet below that of Dhok Pathan, I should not perhaps venture to erect a separate zone to contain its fossils.

Dhok Pathan zone assigned to the upper pontian.

The Fauna of the Chinji Zone

I shall now take up the question of the fauna of the beds, which lie stratigraphically beneath those of Dhok Pathan. I shall pass over for the present the fauna of the Nagri zone because it is poorer in species, and the stratigraphical position of all the fossil localities is not clear, and proceed at once to a consideration of the rich fauna of Chinji.

The precise level at which many of the Chinji fossils were found is uncertain. This is partly because the native collectors can seldom recall the exact spot from which they obtain individual specimens,

Precise levels at which the fossils were found.

and partly because in a labyrinth of barren hills it is often difficult to locate accurately any particular fossil locality. This much is, however, certain, that the basal beds have yielded the smaller number, while the topmost beds have also yielded very few. The mass of the specimens were collected from more than 400 and less than 2,000 feet above the level at which I place the base of the Lower Chinji zone.

The following species have been only found in the 800 feet of Upper Chinjis, *Hipparion sp.*, *Palaeoryx sp.*, *Hyaena sp.*, *Sivapithecus indicus* and a primitive Semnopithecine monkey, which probably represents a new generic type (see p. 288).

The following species have been found both in the Upper as well as the Lower Chinjis, *Listriodon pentapotamiae*, *Amphicyon cf. giganteus*, *Giraffokeryx punjabiensis*, *Dinotherium indicum*, *Tetrabelodon macrognathus*, *Dorcatherium minus*, *Hemimeryx pusillus*, *Protragocerus sp.*, *Sus sp.*

The following species have been found in the basal beds, *Dinotherium indicum*, *Listriodon pentapotamiae*.

The localities of the others are uncertain. Under these circumstances it seems most convenient to omit from the Chinji fauna those species which occur only in the Upper Chinji zone, and to assume that the remainder of the fauna is that of the Lower Chinji zone. This is an assumption which may give rise to a small error, supposing it should be the case that certain newer types do not occur in the lower horizon. The difference, however, cannot be great and in any case we shall not be led to assign to the Lower Chinjis an *older* age than the fauna warrants. It is this fauna of which a list appears in the table on pages 280-287.

Analysis of the Lower Chinji fauna.

We may analyse this fauna as follows :—

(1) The species ancestral to the "Hipparion fauna" of Pikermi and Samos, that is the forerunners of the migratory types which did not reach Europe until the pontian.

(2) Endemic species which represent exclusively Asiatic types. Some of these are ancestral to Middle Siwalik species, which, however, did not penetrate to Europe and so do not compose the "Hipparion fauna" of Pikermi and Samos.

(3) Species related more or less closely to those which inhabited Europe in times previous to the pontian. This similarity of character the tortonian-sarmatian faunas of both

Europe and Asia would owe to a similar descent from common ancestors belonging to a period when physiographical conditions permitted quadrupedal types to pass freely between the two continents. That such a period of intermigration existed is shown by the close relation between the faunas of Europe and India in upper aquitanian times. That such intermigration may have continued into the tortonian is, however, not disputed.

The first group includes the *Giraffidae*, certain Bovine antelopes and *Sivaelurus*, the ancestral type of *Paramachaerodus cf. schlosseri* (see p. 314 foot note). It has already been mentioned under each of these heads in the Dhok Pathan section that the Lower Chinji species are in every case more primitive.

Comparison of the Chinji fauna with that of Dhok Pathan.

The second group includes the tetraselenodont branch of the Anthracotheroids and the traguloid *Dorcabune*. Here, too, the species *Hemimeryx pusillus* is less specialized than the Middle Siwalik *Merycopotamus*.

It may also be noted here that the members of the third group which are represented in the Middle Siwaliks are in every case less advanced than their Middle Siwalik descendants. Thus, the *Mastodon cautleyi-Steyodon* line is entirely absent even in its earliest stages; the *Mastodon* of the type of *arvernensis* has not yet appeared. On the other hand, species allied to *Tetrabelodon angustidens* are present. An interesting discovery in the Upper Chinjis of an absolutely perfect mandible of a species of *Tetrabelodon* exemplifies this point well. This species seems, as nearly as one can say, to have been the direct ancestor of the Middle Siwalik *Tetrabelodon punjabiensis*, the affinity of which with the European *T. longirostris* has already been noted (page 293). Possessing teeth of an exactly similar type, it differs from it by the rather more complicated talon in the last molar, by the greater prominence of the accessory columns, by the intermediate molars being trilophodont instead of tetralophodont, and finally by the very much more elongated symphysis. It is very remarkable to observe that the length of the symphysis is proportionately greater not only than that in *T. corrugatus* of Dhok Pathan but also than it is in *T. longirostris* and *T. angustidens*, which leads us to imagine that the Upper Chinji species, for which I propose the name of *Tetrabelodon macrognathus*, represents a very early stage of development.

The following table of approximate measurements in millimetres of the mandible in these different species will show this at a glance.

	T. macrognathus.	*T. angustidens.*	*T. longirostris.*	*T. punjabiensis.*	*T. corrugatus.*
Total length from articulation to tip of tusk.	1,530	1,350	960	..	..
Total length from articulation to end of symphysis	1,480	1,215	760	..	..
Length of symphysis . .	810	550	320	330	580
Length of jaw behind symphysis	670	665	440	..	..
Length of last lower molar	236	207	200	250	208

In the Suidae the most important types are *Listriodon* and *Hyotherium*. *Sus* occurs as a species which is far more primitive than any of the Dhok Pathan pigs. *Hyotherium* dies out in the Nurpur zone, giving, rise only to the extremely specialized *Tetraconodon*. *Listriodon* alone exists as a rare survival, being perhaps not specifically distinct from the Chinji *Listriodon pentapotamiae*. *Amphicyon* survives in the Middle Siwaliks, but the species differs from that of Chinji by the squarer form of its teeth, thus approximating to *Dinocyon*. The creodont *Dissopsalis*, the anthropoid *Dryopithecus*, and some of the primitive Viverrid and Mustelid genera have disappeared. *Dorcabune* possibly was found at Hasnot but the species, originally described by Lydekker as *Anthracotherium silistrense* is very much more hypsodont and less Anthracotheroid than the Chinji species.

Summary.

Thus, to sum up, there is hardly a species in common between the Lower Chinjis and the Dhok Pathan zone. Identities may exist in *Dinotherium indicum*, *Listriodon pentapotamiae*, and *Microbunodon silistrense*. But all three are species on the point of extinction, and for that reason little susceptible of alteration. Not only are the species different in the two zones, but these differences have advanced as far as the generic stage in numerous cases, while numerous old lines come to an end in the Lower Chinjis. Taking all this into consideration, considerably more than a substage should be placed between the two zones. If we exclude the migratory forms from the fauna of any one European stage in the miocene, we shall find that the resemblances to the fauna of the stage below are much closer than they are between the Dhok Pathan fauna and that of the Lower Chinjis. Therefore, if we assume the Dhok Pathan zone to be upper pontian it is not too much to expect the Lower Chinji zone to reach into the tortonian, but at least it must take us to the base of the sarmatian.

As I have suggested above (p. 273) the thickness and frequency of concretionary pseudo-conglomerates throughout the Chinji beds renders it exceedingly probable that a considerable interval elapsed between the deposit of the basal and the topmost beds. If correct this would warrant us in putting the basal beds of the Lower Chinjis into the tortonian.

Comparison of the Chinji fauna with Miocene faunas of Europe.

Both of the preceding arguments are based on geological reasoning, or on the stratigraphical, and faunal relations of the Chinji horizon to the Dhok Pathan beds, on the assumption that the Dhok Pathan zone is upper pontian. Strong as is the evidence for this assumption and the deductions which follow from it, I shall now see how far a direct comparison of the Lower Chinji fauna with that of the tortonian and sarmatian of Europe supports the conclusion arrived at above.

Of the three classes into which we have seen that the Chinji fauna can be divided, the first two must obviously consist of species which are quite unrelated to any that appeared in Europe previously to the pontian. Hence, we need only consider the third category of species.

Primates.

Of the Primates *Dryopithecus* is a very characteristic genus of the Chinji zone. The species *D. indicus* approaches *D. fontani* of Saint Gaudens very nearly but differs by the more inward position of the mesoconid, the absence of a anterior cingulum and by the greater wrinkling of the enamel. In the latter character it is nearer to *D. darwini* of the tortonian. It is exceedingly doubtful whether *D. rhenanus* is newer than sarmatian, but in any case it differs from the Chinji species by the entire absence of a basal cingulum.

Carnivora.

Amongst the Carnivora the most striking feature is the survival of a creodont related to *Sinopa* one of the *Hyaenodontidae*. *Sinopa* is not known later than the Eocene, and the last Hyaenodont known is from the stampian. It should be noted that the mandible briefly described[1] as that of *Dissopsalis*, under the mistaken impression that it was associated with the maxilla, turns out to have come from the Upper Chinjis, from a spot whence I have since obtained other remains of the same species, if not the same individual, and is really a species of *Hyaena*. Other lower teeth have, however, been found in the Lower Chinjis, which are certainly creodont and present the same characters that one would expect in *Dissopsalis*. It can of course only be regarded as a curious survival, although its occurrence gives a very ancient look to the Lower Chinji fauna.

The Ursidae have unfortunately not yet been found in the Lower Chinjis.

Amphicyon is largely represented, one of the species being indistinguishable from one which has been found in Europe from the burdigalian upward.

Remains of the Mustelidae are rather frequently found at Chinji, but they are generally so fragmentary that it is difficult to be sure of their genus. The general facies of this part of the fauna reminds one strongly of that of the tortonian of La Grive Saint Alban. One species may be referred to the genus *Haplogale*.

The Viverrids are represented at Chinji by the tortonian genus *Progenetta*, the species *P. proava* (formerly referred to *Palhyaena*) being very close to *P. crassa*.

The Felidae are represented by *Machaerodus*, but the remains are so fragmentary that it is difficult to compare them satisfactorily with European species.

Proboscidea.

As in the sarmatian and tortonian of Europe *Dinotherium* is represented by smaller species than in the pontian.

The Mastodontidae are all trilophodont and tetrabelodont. A variety of *Tetrabelodon angustidens* is met with, while even in other lines of *Tetrabelodon*, the elongation of the mandibular symphysis is as great or greater than in Middle Miocene specimens of *T. angustidens*, as demonstrated on page 310.

Perissodactyla.

The Rhinocerotidae are represented both by a *Teleoceras* and an *Aceratherium*. The former shows an advance on *Teleoceras blanfordi*, and the latter is in the same stage of development as the sarmatian *A. tetradactylum*.

[1] *Rec., Geol. Surv., Ind.*, XL, p. 64.

Listriodon and *Hyotherium* are the two lines of the Suidae which predominate in the Chinji beds. They are also a marked feature of the sarmatian and tortonian of Europe. Moreover, the species *Hyotherium cf. sindiense* and *Listriodon pentapotamiae* are almost indistinguishable from certain varieties of the European tortonian species *Hyotherium simorrense* and *Listriodon splendens*. Although *Hyotherium* and *Listriodon* are the dominant Suidae, yet there is a *Sus*, which by its short last molar and its large anterior molars, seems to be an advance on the type of *Hyotherium sommeringii*. This genus is absent from the tortonian, the species described by C. Gaillard as *Sus grivensis* from La Grive Saint Alban, having been referred by H. G. Stehlin to a variety of *Hyotherium simorrense*. A true *Sus*, however, occurs in the sarmatian of Monte Bamboli.

Suidae.

The genus *Choerotherium* which is certainly found in the tortonian and appears to be present also in the Saint Gaudens zone, has not so far appeared at Chinji.

Dorcatherium is a common fossil at Chinji. There are several species, some of which come very near the European species, while the species *Dorcabune anthracotheroides* seems to show many points of resemblance to *Dorcatherium crassum*.

Tragulidae.

A primitive cervuline with horn cores something like *Dicroceros*, also occurs at Chinji.

Cervidae.

The antelopes are presented by four species of which one is obviously related to the Gazelles, and may be compared to *Gazella* (?) *gracillima* of the sarmatian of Monte Bamboli, while two others are primitive members of the *Tragocerinae*, having horn cores exceedingly like *Protragocerus chantrei* of the tortonian, and *Antelope* (*gen. ind.*) *clavatus* of the tortonian. The fourth has flat horns with just the beginning of a spiral twist, which I regard as ancestral to the pontian *Taurotragus* (?) *latidens*.

Bovidae.

To sum up, if we compare the species in the Lower Chinji fauna which belong to the 3rd of my three divisions, with those of the pontian fauna of Europe which have been locally developed, we cannot avoid the conclusion that the lower Chinji fauna is very much more primitive. *Amphicyon*, primitive types of the *Mustelidae* and *Viverridae* such as *Haplogale*, *Potamotherium*, and *Progenetta* and of the Suidae as *Hyotherium*

Summary.

and *Listriodon* and perhaps *Dryopithecus* amongst the Anthropoids, have disappeared before the pontian stage of Europe. On the other hand, the Ursidae have developed considerably and *Hyaenarctus* and *Ursus* itself have become conspicuous. *Sus* is represented by many species, amongst them being the large *Sus major* which is certainly more advanced than the *Sus* of the Chinji beds. Amongst the Proboscidea only the larger *Dinotherium* survives; the *Mastodontidae* have reached the tetralophodont stage and the *T. angustidens* type has died out. Both *Aceratherium incisivum* and *Teleoceras goldfussi* are more advanced than any of the Lower Chinji Rhinocerotidae. Finally, the Tragocerinae have arrived at a more hypsodont stage and have larger, more specialized horns than the Chinji antelopes belonging to this family.

It will have been seen that those of the European species which can be paralleled by Chinji forms occur equally in the sarmatian and tortonian of Europe. In deciding between the claims of the two stages to receive the Lower Chinji beds, we have to set on the one side the very close relationship of *Hyotherium cf. sindiense* to the tortonian *Hyotherium simorrense*, and on the other, the fact that certain primitive types such as *Trochictis* and *Pseudaelurus* [1] are absent both from the Lower Chinjis as well as from the sarmatian, while *Sus* and gazelle-like antelopes which are found both at Monte Bamboli and Chinji, are absent from the older tortonian beds of La Grive Saint Alban. I am, therefore, not inclined to correlate the Lower Chinji zone with an earlier stage than the sarmatian.

The Fauna of the lower Manchhar Zone.

We will now consider the lowest beds of the Siwalik series, of which the fauna is only known from Sind and the Bugti hills, while their stratigraphical relations to the newer fossiliferous zones can only be seen in the Salt Range. Therefore, the correlation of the fossiliferous beds of the one area with the unfossiliferous beds of the other admits of a slight doubt, a fact to which I

[1] The maxilla briefly described in *Rec., Geol. Surv., Ind.*, XL, p. 65, under the name of *Pseudaelurus chinjiensis* turns out on further comparison to be generically distinct. The main differences consist in (1) the entire absence of a diastema, (2) a longer pm.^{3}, (3) a feebler and less trenchant canine, (4) presence of a strong, outer, anterior cingular cusp in pm.^{4}. It appears to be ancestral to the type of *Machaerodus orientalis* Kittl. from Maragha. I propose for it the new generic name of *Sivaelurus*.

have already called attention (page 268). The difference is, however, not likely to be great, and we cannot be far wrong in putting the beds of both areas into what I may call the lower Manchhar zone, this being the name first given to the Sind beds by Blanford.

In my "Preliminary Note" I did not feel in a position to do more than estimate their age roughly. Two methods were made use of, one based on the observed conformable passage of the upper aquitanian Kuldanas into the Murrees and of the Murrees into the Lower Siwaliks,[1] the other on a certain amount of similarity existing between the vertebrate fauna of the Gaj of the Bugti hills and the Lower Manchhars of Sind. The conclusion arrived at was that we should place the base of the Lower Siwaliks no later than tortonian. The first of these methods is confessedly inexact, because we do not know how much time we should allow for the accumulation of the Murree sediments. At the same time, seeing that the maximum thickness of the latter is quoted as 8,000 feet, we must, judging by probability only, presume that the period was a considerable one, though it seemed unreasonable to make it include more than the burdigalian and helvetian stages.

The second is also inexact, because there are no actual identities between the two faunas, and at that time one had only two Indian faunas with which to compare the Lower Manchhar vertebrates, that of Dhok Pathan and Hasnot and that of the Gaj of the Bugti hills, the former being pontian and the latter upper aquitanian, so that the most I could attempt to show was that the affinities with the older of the two were too close to warrant our putting the Lower Siwaliks any further away than the tortonian.

To this, however, I can now add the following evidence, of which I was unaware when I wrote my former paper. Below the lower Chinji horizon, which has been shown to be certainly no newer than the base of the sarmatian, 1,700 feet of deposit occur, a deposit, moreover, which on account of the frequency of pseudo-conglomerate bands was quite likely to have extended over a considerable period, so that if we considered the base of the Lower Manchhar zone as contemporaneous with the base of the European tortonian, we should be doing no more than the stratigraphical

[1] Pilgrim, *op. cit.*, p. 190.

facts warrant. We can also infer through geological reasoning that the fauna of the lower Manchhars of Sind occurs at least 1,600 feet lower than that of Chinji. We can, therefore, proceed to compare the Lower Manchhar fauna on the one hand with that of the Gaj of the Bugti hills and on the other with that of the Chinji beds, with rather more chance of reaching an accurate conclusion. At least we may be able to confirm the age of the Lower Manchhar as arrived at by other means. Unfortunately, the Lower Manchhar fauna is very scanty. Since W. T. Blanford and F. Fedden surveyed Sind in 1875-77 no mammalian collections have been made from that area. This omission it is the intention of the Geological Survey of India to remedy at the earliest possible opportunity. The fauna is also of a rather endemic character, so that it is impossible to institute very minute comparisons with that of the European Miocene. We must, therefore, be content with a comparison with the two Indian faunas of whose age we are approximately sure.

There follows a list of the Lower Manchhar species arranged in parallel columns with allied types of the Gaj zone and the Lower Chinji zone.

Gaj zone.	Lower Manchhar Zone.	Lower Chinji Zone.
Amphicyon shahbazi .	Amphicyon sp. . . .	Amphicyon sp. aff. giganteus.
		Amphicyon palaeindicus.
		Amphicyon sp.
Dinotherium naricum .	Dinotherium pentapotamiae	Dinotherium pentapotamiae.
	Dinotherium sindiense.	Dinotherium sp.
Hemimastodon crepusculi	Tetrabelodon angustidens var. palaeindicus.	Tetrabelodon angustidens var. chinjiensis.
Tetrabelodon aff. pandionis	Tetrabelodon pandionis .	. .
. . . .	Tetrabelodon falconeri .	Tetrabelodon falconeri.
		Tetrabelodon macrognathus,
		Tetrabelodon sp.
	Acerathexium sp. . .	Acerathérium perimense.

Gaj zone.	Lower Manchhar Zone	Lower Chinji Zone.
Aceratherium gajense .	Aceratherium gajense var. intermedium.	
Teleoceras blanfordi .	Teleoceras blanfordi var. .	Teleoceras blanfordi var.
Phyllotillon naricus . .	Phyllotillon sirdense .	Phyllotillon sp.
Microbunodon mus . .	Microbunodon sp. . .	Microbunodon silistrense.
Brachyodus africanus .	Brachyodus sp. . .	
Hyoboops naricus . .	Hyoboops palaeindicus .	
Hemimeryx affinis . .	Hemimeryx blanfordi .	Hemimeryx pusillus.
Telmatodon bugtiensis .	Telmatodon (?) sp. . .	
	Chocromeryx silistrensis .	
	Hyotherium sindiense .	Hyotherium cf. sindiense.
Listriodon affinis . .	Listriodon sp. . . .	Listriodon pentapotamiae.
		Listriodon sp.
		Sus sp.
	Dorcabune anthracotheroides.	Dorcabune anthracotheroides.
Dorcatherium sp. . .	Dorcatherium minus .	Dorcatherium minus.
		Dorcatherium sp.
Propalaeomeryx exigua .	Propalaeomeryx aff. exigua	Propalaeomeryx sivalensis.

Analysis of the lower Manchhar fauna.

Out of twenty-one species, which have up to now been discovered in the Lower Manchhar fauna, only seven, or a third are identical with Lower Chinji species. There is a not single identity with the Gaj species of the Bugti hills but six of them are closely allied to Gaj species. Moreover genera, which have died out before Chinji times, still survive in the Lower Manchhars. Such are *Brachyodus, Telmatodon, Hyoboops,* and that type of *Hemimeryx*, in which the hypoconal crescent is imperfect. Moreover, there is reason to believe that the genus *Sus* had not yet appeared at the period when the Lower Manchhars were deposited. The Hyotheroid material from the Lower Manchhars is insufficient to enable us to say whether the species *Hyotherium sindiense* Lyd. is the same as the species which I have found at Chinji, and which I have referred to as *Hyotherium cf. sindiense.* The latter is undoubtedly closely allied to the European *H. simorrense*, but the Sind species may represent another type. It may be remembered that the Perim Island *Hyotherium perimense* Lyd. is certainly the descendant of a more primitive line, and also that the *Sus* of the Chinjis is unconnected with the *Hyotherium cf. sindiense* of Chinji, and seems rather to have been derived from some form like *Hyotherium sommeringii.*

It must not be forgotten that this fauna occurs in the lowest 100 feet, but its character entirely confirms the conclusion arrived at by other means that the 1,600 feet of deposit, which is the minimum that can be assumed between the fossiliferous zone of the Lower Manchhars and the base of the Lower Chinjis, corresponds to a considerable period. It is doubtful whether the difference between the Gaj fauna of the Bugti hills and that of the lower Manchhars is sufficiently great to warrant our putting two stages between them, while on the contrary the alliance between the Lower Chinji fauna and that of the Lower Manchhars is not close enough to suggest our placing less than a stage between them. Consequently, it is exceedingly likely that the fauna of the basal beds of the series is lower tortonian. Without, however, venturing on such minute classification, we may safely call the Lower Manchhar zone tortonian, that is the equivalent of the stage of Simorre.

The Fauna of the Nagri Zone.

Fauna of Nagri.

The fauna of Nagri, the stratigraphical position of which was briefly referred to on page 267, shows very marked indications of being in an intermediate stage between that of Dhok Pathan and the Upper Chinjis. The fauna is a smaller one than that of either of these zones. If the material were more abundant we should no doubt be justified in referring several forms to species distinct both from those of Chinji and Dhok Pathan. At present all I can do is to indicate the affinities of the different types so far discovered, which are as follows :—

Hipparion cf. theobaldi.
Hipparion sp.

Aceratherium cf. perimense, distinct from any Chinji species and also from the Dhok Pathan *Aceratherium lydekkeri.*

Aceratherium sp.

Antelope (*Palaeoryx* ?) large species.

Antelope much smaller and perhaps ancestral to the Dhok Pathan *Antelope n. gen. latidens* Lyd. sp.

Antelopes of a smaller type allied to Upper Chinji species (*Protragoceros* ?).

Large Giraffoid referable to *Bramatherium* or *Hydaspitherium.*

Giraffokerya sp. a larger species than *G. punjabiensis.*

Dorcabune sp. smaller than *D. anthracotheroides.*

Dorcatherium majus.

Dorcatherium minus.

Hyotherium indicum Lyd. sp., identical with the species of which Lydekker figured the lower premolar as *Hyaenodon indicum.* This specimen came from an unknown horizon at Kushalgarh. The type represents a slight advance on *Hyotherium cf. sindiense* of the Chinji beds in the direction of *Tetraconodon,* and has not so far been found in the Chinji beds.

Lycyaena sp. cf. macrostoma.

Hemimeryx pusillus.

Chalicotheroid *genus* and *species indet.*

Fauna of Hari Talyangar.

This fauna is paralleled by one which has been found by Sub-Assistant Vinayak Rao at Hari Talyangar in the Belaspur State near the Kangra boundary, in the Sub-Himalayan area. This fauna has been referred to above on page 270. The geological evidence as a whole suggests a horizon about the same level as that of Nagri, or if anything only slightly newer. The character of the fauna, which is described below is in entire agreement with this conclusion.

Hipparion cf. theobaldi.

Hipparion sp.

Antelope same as the Nagri species, smaller than and probably ancestral to *Antelope n. gen. latidens* Lyd. sp.

Antelopes of a smaller type allied to Nagri forms.

Large Giraffoid perhaps referable to *Bramatherium* having two distinct lobes to the last column of the 3rd lower molar.

Giraffokeryx same species as found at Nagri.

Giraffa small species.

Dorcabune sp. same species as at Nagri.

Dorcatherium majus.

Dorcatherium minus.

Hyotherium (?) *sp.*

Listriodon sp.

Sus sp. smaller than but of the same type as, the Dhok Pathan *Sus titan.*

Potamochœrus sp. various.

Sus sp. various.

Anthracotherium sp. larger than *Microbunodon silistrense* and belonging to an entirely different line.

Chalicotherium sp.

Rhizomys. sp.

Lepthyœna sp. much smaller than *L. sivalensis.*

Progenetta (?) *sp.* larger than *Progenetta proava* from Chinji and smaller than the Dhok Pathan *Palhyœna indica.*

Palœopithecus sp. smaller and probably more primitive than *Palœopithecus sivalensis* of the Dhok Pathan zone.

A consideration of these faunas shows us that while many of the Dhok Pathan species are represented by allied types, the latter in very many cases bear signs of being ancestral to the former. On the other hand, a few genera which are unknown in the Dhok Pathan zone occur. These are in all cases Chinji genera but the species do not appear to be the same as have been found in the latter beds. It is, therefore, apparent that this fauna displays an intermediate character between that of the Dhok Pathan and Chinji zones, as in fact its stratigraphical position would lead us to surmise, but farther than this we cannot go.

Fauna of Perim Island.

The fauna of Perim Island presents the same intermediate character as that we are discussing. The genus *Hyotherium* has not been found in the Salt Range area in strata newer than the Chinjis. The species *Hyotherium perimense* Lyd. (referred by H. G. Stehlin to the genus *Palœochœrus*) may, however, represent a later survival. On the other hand, Mastodons of the type of *M. Cautleyi* are entirely absent from the rich Proboscidean fauna of the Chinji zone. *Hipparion* seems to have been so abundant as to imply a more recent date than the Upper Chinjis for the Perim Island beds. Moreover, the original *Hipparion* cranium from Perim Island figured by Lydekker has now been examined[1] and proves to be specifically inseparable from *Hipparion punjabiense* of Dhok Pathan, so that the name *Hipparion perimense* proposed for it myself must be abolished. The large Giraffoid *Bramatherium perimense*, the horn cores described and figured by Lydekker under the name of *Capra perimensis*, and subsequently referred by myself to the genus *Tragocerus*, the maxilla referred to *Merycopotamus*, the large antelope referred provisionally by Lydekker to *Strepsiceros* with the specific name of *falconeri* (which is, however, entitled in my opinion, to receive another new generic name, see above p. 303) and finally the identity of a 1st upper molar figured in the *Fauna Antiqua Sivalensis*, pl. XL, fig. 3, 3*a* and Pal. Ind., ser. 10, Vol. III, p. xv, text fig. 5 with the corresponding tooth in a maxilla from the Punjab (Ind. Mus. A 48) figured in Pal. Ind. ser. 10, Vol. I, Pl. XL, point no less than in the same direction. Unfortunately Proboscidea, which are so abundant in Perim Island, have not been found either at Nagri or Hari Talyangar, so that a close comparison is impossible. Provisionally, however, I shall correlate the Perim beds with those of the Nagri zone.

The Fauna of the Tatrot Zone.

In dealing with the Upper Siwalik faunas, there must exist a strong element of uncertainty as to the precise zone in which to place a certain number of the species which we know only from the specimens collected by H. Falconer and his co-workers, or thirty years later by W. Theobald, but which have not been rediscovered since.

The list of the fauna of the Tatrot zone is based entirely on the species found in the lowest beds of the Upper Siwalik at Tatrot, Kotal Kund, Bhaun and other places in the Salt Range area, where the stratigraphical relation of this bed to the middle Siwaliks is known with certainty. On the other hand we are in some cases uncertain whether we should not include with these certain species recorded amongst Theobald's collections from Hasnot but not found by myself. It is also an assumption on our part to limit these species to the Tatrot zone seeing that the Pinjor zone above is not rich in either species or individuals. Moreover, although

[1] This cranium was found in the collections of the College of Science, Poona, the authorities of which have generously presented it to the Geological Survey. It was described and figured by Lydekker in Pal. Ind. (10) III, p. 11, pl. iii under the name of *H. antilopinum* Falc. and Caut.

all the species found in the Tatrot zone in the Salt Range are among those figured by Falconer in the *Fauna Antiqua Sivalensis*, it is only conjecturally that we can conclude that they were yielded by a contemporaneous zone in the Sub-Himalayan Siwaliks.

Very careful collecting in the hills between the Sutlej and the Jamna would undoubtedly do much to settle the point, but until then it seems reasonable to regard such of the Tatrot species as have not been found in the *Elephas planifrons* beds as limited to the former of these two zones. The occurrence of the genus *Merycopotamus* seems to afford an instance where the application of this principle is justified. Very few specimens of *Merycopotamus* were found in Falconer's time, the exact locality of these not having been recorded. The bulk of our material has been found later in the Middle Siwaliks of the Salt Range. I have, however, come across several specimens in the Tatrot zone in each one of its three fossiliferous localities. Sub-Assistant Vinayak Rao also found a skull of *Merycopotamus* in the basal beds of the Pinjor Range at Basaulan, but not a trace of the genus has come to light from the fossiliferous beds of a higher horizon in the same area. We are, therefore, disposed to presume that the Basaulan locality is a part of the Tatrot zone.

Fauna of the Tatrot zone. The following is the fauna of the Tatrot zone as far as at present known :—

Mastodon sivalensis Falc.

Stegodon clifti and *bombifrons*.

Sus. sp. A large mandible allied to that figured by Lydekker as *Sus. giganteus* in Pal. Ind. ser. 10, Vol. III, Pl. XI, fig. 1, but with even larger premolars.

Sus cf. hysudricus.

Hippohyus sivalensis Falc.

Hippohyus lydekkeri Pilg.

Hippopotamus sp.

Merycopotamus cf. dissimilis.

Sivatherium sp.

Antelopes genera and species various.

Dorcatherium sp.

Leptobos sp.

Hemibos sp.

Amphibos sp.

Hipparion sp.

This fauna is not of such a character as enables us readily to compare it with that of any European one, but the sudden influx of Bovine genera and *Hippohyus*, and the leap into prominence of the genus *Hippopotamus* which is exceedingly scarce in the Dhok Pathan zone, serves to emphasise its distinctness from the fauna of the latter.

The Fauna of the Pinjor Zone.

Still less is accurately known about this horizon of the Upper Siwaliks. In the Salt Range area our acquaintance with it is confined merely to finds of *Elephas planifrons* at various places from 2,000 to 3,000 feet above the top of the Middle Siwaliks, and of *Elephas planifrons*, *Leptobos*, and the horn of a large *Cervus* some 2,000 feet below the boulder conglomerates.

In the Sub-Himalayan area we find some 3,000 feet of strata exposed in the Pinjor range situated east of the river Sutlej and abutting on the plains. The topmost beds exposed at Rupar do not contain any boulder conglomerate to speak of, and may only include the base of the upper zone, the higher beds being either denuded or concealed beneath the alluvium. That they belong to the uppermost zone is, however, rendered exceedingly probable by the occurrence in them of *Camelus* and *Equus*. On the other hand the beds at the very base of the series, as has been already mentioned (p. 322), have yielded *Merycopotamus*, and there is therefore some probability that they reach into the Tatrot zone. Between these limits, however, the remainder of the beds which constitute the bulk of the whole are assigned to what I have named the Pinjor zone. I should mention that we are indebted to Sub-Assistant Vinayak Rao for the examination of this range, and he is responsible for the stratigraphical details given above. *Elephas planifrons* occurs abundantly in these beds with *Stegodon*, *Hippopotamus*, *Amphibos*, *Leptobos*, *Hemibos*, *Hipparion*, *Sus sp. cf. hysudricus* and Antelopes genera and species various.

If we accept G. Schlesinger's discovery of *Elephas planifrons* in the Middle Pliocene of Austria as a proof of a similar age for the beds containing *Elephas planifrons* in India (see page 294), then we may regard the lower portion of the Pinjor zone as Middle Pliocene, and as there is good reason to believe that the overlying boulder conglomerates are uppermost Pliocene it is likely that the Pinjor zone is in part Upper Pliocene.

The Fauna of the Boulder Conglomerate Zone.

There is a very strong probability that this horizon is the one which has yielded the bulk of the fossils collected from the outer ranges of the Sub-Himalayas. Its stratigraphical relation to the other fossiliferous zones of the Siwaliks is clearly shown by the correlation of this zone in the Sub-Himalayas with beds of known stratigraphical position in the Salt Range. Proof of this correlation is found in (1) the presence of the very characteristic boulder conglomerates in both regions, (2) the occurrence of the characteristic zone fossils *Elephas hysudricus*, *Equus* and *Camelus* alike in the Salt Range and in the Sub-Himalayan Siwaliks and their apparent absence from beds some 2,000 feet lower in the series :—

The following is a list of the species whose occurrence in the boulder bed zone may be regarded as certain :—

Melursus theobaldi
Mellivora sivalensis
Vulpes curvipalata
Hyæna colvini
Machærodus sivalensis
Felis cristata
Felis sub-himalayana
Hystrix sp.
Stegodon ganesa and *insignis*
Elephas hysudricus
Dicerorhinus platyrhinus
Rhinoceros sivalensis
Equus sivalensis
Equus namadicus
Chalicotherium sivalense
Sus falconeri
Potamochœrus hysudricus
Hippopotamus sivalensis
Camelus sivalensis
Camelus antiquus
Sivatherium giganteum
Indratherium majori
Bubalis palæindicus
Cobus patulicornis
Cobus palæindicus
Cobus gyricornis
Hippotragus sivalensis
Boselaphus sp. cf. namadicus
Buffelus palæindicus
Buffelus platyceros
Bos acutifrons
Bos planifrons
Bos platyrhinus
Bison sivalensis

We lack complete proof of the exact horizon whence the following species were obtained although it is very probable that they are to be assigned to the same as the ones detailed above.

Papio sub-himalayanus
Canis cautleyi
Hyæna felina
Rhinoceros palæindicus
Hemitragus sivalensis
Bucapra daviesi
Hemibos antilopinus
Hemibos triquetricornis

Regarding the remainder of the fossils collected in the Siwalik hills we know nothing of their stratigraphical horizon except that they belong to the Upper Siwaliks. We can only conjecture that most of them came from high up in the series, although it is quite as reasonable that some should belong to the Pinjor or even the Tatrot zone.

They are as follows :—

Simia sp. cf. *satyrus*	*Cynælurus brachygnathus*
Semnopithecus palæindicus	*Nesokia* sp. cf. *hardwickii*
Papio falconeri	*Rhizomys* sp.
Hyænarctos sivalensis	*Caprolagus sivalensis*
Mustela sp.	*Potamochoerus giganteus*
Enhydriodon sivalensis[1]	*Potamochoerus magnus*
Lutra palæindica	*Giraffa sivalensis*
Hyæna sivalensis	*Moschus* (?) *sp.*
Viverra bakeri	*Cervus sivalensis*
Viverra durandi	*Tetraceros daviesi*
Machærodus palæindicus	*Amphibos acuticornis*

Age of the Boulder Conglomerate zone.

Respecting the age of this uppermost zone of the Upper Siwaliks we have no reason to suppose that the genera *Equus* and *Camelus* appeared earlier in India than they do in North America. *Equus* is characteristic of the Peace Creek beds of Florida and the Loup River of Nebraska, which are assigned by H. E. Osborn to the Upper Pliocene or Lower Pleistocene, while *Camelus* is considered by Osborn to occur in beds of the same age in California. In Europe *Equus* occurs in the Upper Pliocene of Italy, while the remains of *Camelus* have been found in Northern Africa associated with Palæolithic implements of a Chellean type. The latter would seem to be an emigrant from India. Confirmatory evidence as to an Upper Pliocene or lowest Pleistocene age for this fauna is afforded by the presence of *Elephas hysudricus*, which H. Pohlig considers a variety of the Upper Pliocene elephant of Europe *E. meridionalis* and of *Dicerorhinus platyrhinus*, which is structurally related to the Upper Pliocene *Dicerorhinus etruscus* of Europe. An approximation in age to the *Elephas antiquus* beds of the Narbada, which are certainly Pleistocene, is suggested by the occurrence of the species *Buffelus palæindicus*, *Equus namadicus and Boselaphus cf. namadicus*. The first two of these three species were found by Lydekker himself at the very top of the Siwaliks and on the strength of them he suggested the possibility that these *topmost* beds were lowest Pleistocene.[2] We may therefore safely regard this zone as uppermost Pliocene, while not in the least disputing Lydekker's suggestion that the uppermost Siwaliks touch the Pleistocene.

[1] The occurrence of *Enhydriodon cf. sivalensis* in the Dhok Pathan Zone and of *Enhydriodon campani* in the sarmatian of Monte Bamboli makes it probable that it was not found at a horizon later than that of Tatrot.

[2] *Pal. Ind.* ser. 10, Vol. II, p. 96.

EXPLANATION OF PLATES.

PLATE 26.—Table showing the classification of the Tertiary River Deposits of India.

PLATE 27.—Geological map of the eastern portion of the Salt Range area showing the distribution of the Siwaliks.

PLATE 28.—Fig. 1. Section between Chambal ridge and the Jhelum river.
Fig. 1*a*. Section further to the east than fig. 1.
Fig. 2. Section between the Soan river and the Salt Range.
Fig. 3. Section between the village of Bhaun and the Salt Range.

CONTRIBUTIONS TO THE GEOLOGY OF THE PROVINCE OF YÜNNAN IN WESTERN CHINA. III. NOTES ON THE STRATIGRAPHY OF THE ORDOVICIAN AND SILURIAN BEDS OF WESTERN YÜNNAN. BY J. COGGIN BROWN, M.SC., F.G.S., *Geological Survey of India*, WITH PROVISIONAL PALÆONTOLOGICAL DETERMINATIONS BY F. R. COWPER REED, M.A., F.G.S.

The following remarks on the stratigraphy of the Ordovician and Silurian beds of Western Yünnan, are based on notes made during the course of rapid traverses across the areas wherein they are exposed, and are therefore somewhat brief and incomplete. At the same time, taken together with Mr. Cowper Reed's provisional determinations of their faunas, they mark a great advance in our knowledge of these systems as developed in Western China.

The four localities concerned are conveniently referred to as the Pu-piao, La-mêng, Shih-tien and Pai-ma exposures. In the year 1880, L. von Loczy obtained cystidean plates near Pu-piao, belonging to an undetermined species of the genus *Hemicosmites*, (similar to those which are so common in the Naungkangyi beds, and are supposed by Mr. Cowper Reed to belong to *Caryocrinus*), and very imperfect remains of trilobites.[1] He was thus the first to make known the presence of Ordovician strata in Western Yünnan, but no further work was done on them until my own expeditions took place in the years 1908-10.

Pu-piao locality—Approximate position, Lat. 25° 2′, Long. 99° 6′.

In his account of the geology of the Northern Shan States, Mr. La Touche has already drawn attention to the faunas from Pu-piao and Shih-tien, mentioning my opinion that the rocks of the first locality are identical with the Naungkangyi beds, and adding his own, that the cystideans from Shih-tien, resemble in their mode of preservation and other characters, the peculiar forms from Sedaw in the Shan States.[2]

[1] Reise des Grafen Bela Szechenyi in Ostasien, Vol. 1, p. 767; Vol. III, p. 21.
[2] *Memoirs Geol. Surv. Ind.*, Vol. XXXIX, Pt. 2, p. 117.

The Ordovician beds form a small inlier on the steep hill-side which rises to the north of the Pu-piao plain; a small valley filled with lacustrine deposits of late Tertiary age, drained by a stream flowing north-west to join the Salween, which is only 10 miles away to the west in a straight line. At the top they are covered with limestones which are probably of Carboniferous age, while before the bottom of the hill is reached, they are buried by the tuffs which with associated contemporaneous lava flows, shales and limestones of Carboniferous age, build up the western end of the valley. The whole exposure is not much more than ½ mile wide.

At the top of the hill, underlying rounded masses of greyish, calcite-veined limestones referred to above, a series of reddish-yellow, soft, and occasionally sandy slates is found weathering down into marls and clays. From somewhat poor outcrops of these slates I obtained the fossils (K. 15. 298),[1] which Mr. Cowper Reed has determined as follows :—

Cheirurus cf. *mitis* Salt.
Leperditia sp.
Primitia sp.
Orthis aff. *Actoniæ* Sow.
Orthis sp.
Cheirocrinus sp.

In a small valley below this point, a hard, nodular limestone is found in bands with soft, shaley laminæ between them. It contains crinoid stems and plates of *Caryocrinus* sp. (K. 15. 297), preserved in pearly white and red calcite. My impression is that these limestone bands form the axis of a narrow, compressed, anticlinal fold, both limbs of which are made up of the fossiliferous slates.

A few hundred yards to the west of this horizon and lower down the hill, a series of very fossiliferous, fine-grained, greenish-grey, hardened shales was found. When fresh, they break with a splintery fracture, but under the action of denudation form heaps of small, angular, greyish-brown fragments. They are highly

[1] The numbers refer to the Palæontological registers of the Geological Survey of India.

contorted, but the strike appears to be north and south The following fossils were obtained from them :—(K. 15. 295)

Ogygites yunnanensis sp nov.
Illænus cf. *Linnarssoni* Holm
Remopleurides cf. *sexlineatus* Ang.
Calymene unicornis sp. nov.
Orthis aff *Bocki* Lamansky.
Hyolithes 2 sp ind
Raphistoma cf *qualteriatum* Schloth
Cyrtolites ? sp
Conocardium sp ?
Ctenodonta sp
Pachydictya ? sp
Cheirocrinus 2 sp
Didymograptus bifidus Hall
Diplograptus sp

Another fossiliferous horizon was discovered in the same series fifty yards further down the hill The rocks which are of precisely similar character, strike north and south, dip west at 40°, and have yielded the following fossils —(K 15 296)

Lichas aff. *verrucosa* Eichw.
Cyphaspis cf *megalops* Mc Coy.
Pliomera sp
Orthis aff. *Actoniæ* Sow.
Cheirocrinus sp.

In the course of an earlier journey across the Pu-piao hill I collected various fossils without separating them into their different horizons, but, in all probability they come entirely from the slates and hardened shales (K 15 294.)

According to Mr Cowper Reed they comprise .—

Illænus cf *atavus* Eichw
Calymene sp
Pliomera sp
Asaphus sp
Primitia sp
Orthis cf. *Bocki* Lamansky.
Orthis cf. *calligramma* Dalm.
Hyolithes cf. *asteroideus* Reed.
Heliocrinus aff. *araneus* Schloth.

Heliocrinus sp.
Protocrinus? sp.
Didymograptus Murchisoni Beck.

The Ordovician rocks are followed by dark reddish tuffs alternating with greyish shales and thin laminæ of sandstone which dip towards the west at moderate angles.

Mr. Reed believes that the fossils numbered "K. 15. 294, 295, 296, and 298, indicate the age of the beds to be Lower Ordovician, and approximately equivalent to the Upper Arenig and Lower Llandeilo. Probably, they correspond to the Hwe Mawng Beds of the Northern Shan States rather than to the Naungkangyi. Most of the species seem to be new though allied to those from these beds." The age of the bed with *Caryocrinus* (K. 15. 297), is uncertain, but the same genus occurs in the Sedaw Limestone of the Northern Shan States.

La-meng Locality. Approximate position—, Lat. 24° 44′. Long. 98° 58′.

La-mêng is a small circle in the Chinese Shan State of Monghkio, on the Lung-ling-Yung-ch'ang Fu route, to the west of the Salween. Near the principal village of this name poor exposures of hard, purple slates were found from which I obtained a few fragmentary fossils (K. 15. 299), comprising the following species :—

Harpes sp.
Ogygites sp.
Orthis aff. *balcletchiensis* Dav.
Plectambonites aff. *Llandeiloensis* Dav.
Heliocrinus sp.

[Mr. Cowper Reed's conclusion that these beds belong to the same horizon as those from Pu-piao, confirms the opinion I arrived at in December 1909, when I visted the locality. Though no junctions are visible owing to the thick soil cap, I believe the beds are faulted down into the old phyllitic and slatey rocks, to which I have given the name "Kao-liang Series," and which probably corresponds with the Chaung Magyi Series of the Northern Shan States.[1] Immediately to the east, metamorphosed older

[1] Contributions to the Geology of the Province of Yünnan in Western China 1. The Bhamo Têng Yüeh area. *Records, Geol. Surv. Ind.*, Vol. XLIII, Pt. 3, p. 188.

Palæozoic limestones come in, and continue down the steep cañon-side of the Salween.

Shih-tien Locality. Approximate Position, Lat. 24° 45'. Long. 99° 12'

The Ordovician and Silurian beds of this locality, crop out on a hill side to the west of the alluvium-filled valley, which forms part of the small Chinese district of Shih-tien, a few miles to the south of Yung-ch'ang Fu, and west of the Salween. On the west they appear to be overlain by the older Palæozoic metamorphosed limestones, identical in appearance with the Plateau Limestone of the Northern Shan States. Towards the east they are covered by the alluvial deposits of the plain.

The following succession was observed commencing from the top of the hill at an elevation of 6,750 feet :—

1. Hard, light grey limestones, apparently unfossiliferous.
2. Red, earthy limestones and dark shaley limestones which contain the following fossils :—(K. 15. 300)

   Illænus cf. *Linnarssoni* Holm.
   Orthoceras cf. *tortum* Angelim.
   Orthoceras cf. *commune* Wahlenberg.
   Orthoceras cf. *scabridum* Ang.
   Orthoceras sp.

3. Over 70 feet of black fissile slates, which in the last 15 feet become more sandy and lighter in colour. Horizons crowded with graptolite remains are found throughout the series though they are somewhat scarcer towards the top. The relations of the slates to the preceding series (2), are obscure, but they are faulted against the next series (4). They contain :—(K. 15. 301).

   Monograptus lobiferus M'Coy.
   Monograptus spinigerus ?
   Monograptus Becki ? Barr.
   Monograptus tenuis ? Portl.
   Retiolites perlatus Nich.
   Climacograptus scalaris ? His.
   Mesograptus modestus Lapw.

These show the age of the beds to be Llandovery.

4. About 10 feet of greenish-grey, nodular marls, containing *Orthoceras* and crinoid stems, and weathering into hard, rounded fragments.

5. Red marls with a roughened, nodular surface, containing *Orthoceras* and crinoid stems. Intercalated with them are thin greenish bands and lenticular beds of a light grey limestone, which are never more than six feet in thickness, and are not continuous over any great horizontal distance. They dip approximately west-north-west at 25°. From the greenish marls and associated limestones the following fossils were obtained :—(K. 15. 302.)

Caryocystis bicompressa. sp. nov.
Heliocrinus fiscella Bather.
Sphaeronis shihtienensis sp. nov.
Sinocystis piroides gen. et sp. nov.
Illaenus caecoides sp. nov.
Bellerophon (*Sinuites*) cf. *rugulosus* Koken.
Holopea sp.
Trochoceras yunnanense sp. nov.
Tricholites sp.
Lituites ? sp.
Orthoceras cf. *scabridum* Ang.
Orthoceras cf. *regulare* Schloth.
Orthoceras 2 sp. ind.

These rocks weather down into very small angular fragments, but when seen in clean, extended exposures are separated into large cuboidal masses by master joints. Their total thickness is about 360 feet, and lower down the dip appears to be in the other direction. From the weathered outcrops of these beds the following fossils were picked up, though it cannot be considered certain that some of them may not have rolled down the hillside from horizons further away. This is particularly so in the case of the specimen of *Camarocrinus asiaticus* which occurs in a different matrix :—(K. 15. 304).

Heliocrinus fiscella Bather.
Heliocrinus subovalis sp. nov.
Heliocrinus ovalus Bather.

Ovocystis Mansuyi gen. et sp. nov.
Echinosphæra sinensis sp. nov.
Sinocystis Loczyi gen. et sp. nov.
Sinocystis yunnanensis sp. nov.
Sphæronis shihtienensis sp. nov.
Camarocrinus asiaticus Reed
Illænus cf. *Linnarssoni* Holm.
Calymene sp.
Clitambonites sp.
Endoceras cf. *Wahlenbergi* Foord.
Endoceras aff. *cancellatum* Eichw.
Orthoceras sp.

6. A series of black, massive shales which contain lines of concretions and of which some 60 feet are visible, these have yielded :—(K. 15. 303.)

Illænus aff. *Schmidti* Nieszk.
Lichas cf. *celorhin* Ang. var. *coniceps* Eichw.
Asaphus aff. *Broggeri* Schmidt.
Clitambonites cf. *ascendens* Pander.
Orthis aff. *Bocki* Lamansky.
Philhedra sp.
Orthoceras cf. *actuum* Ang.
Orthoceras sp.

7. In the next 200 feet only poor exposures of a decomposed igneous rock were found, rotten enough to render its true determination impossible, but, on the soil covered slopes loose blocks of grey, greyish-red, pink and reddish limestones are strewn about. Some of these are quite earthy while others have bands and gashes filled with calcite, and show the remains of cystideans on their weathered surfaces.

8. Small scattered exposures of yellowish and yellowish white, soft, sandy shales with reddish bedding planes, which lower down contain chocolate coloured bands. They are so faulted and contorted that an estimation of their thickness is liable to be erroneous. They have yielded the following graptolites, and like the black shales found nearer the top of the hill, are believed to be of Llandovery age :—(K. 15. 304.)

Monograptus sp.
Diplograptus sp.

9. A considerable thickness of unfossiliferous, dark grey shales much bleached by exposure.

10. Very decomposed, dark—grey igneous rock, with reddish-brown veins, and white patches marking the former position of felspar crystals. This continues down to the level alluvial deposits of the plain at an elevation of 5,120 feet.

Pai-ma locality.

On the ascent to the south-east out of the small Pai-ma valley which lies 10 miles to the south of Shih-tien, I obtained *Monograptus sp.* from a series of black, micaceous slates but a prolonged search revealed no other fossils in these or any of the surrounding rocks.

Conclusions.

Mr. Cowper Reed is of the opinion that the fossils (K. 15. 303 and K. 15. 300) from the dark shaley limestones of Shih-tien suggest the Vaginatenkalk of the Baltic provinces.

"The abundant cystideans and associated fossils marked K. 15. 302, 304, 305 suggest a correlation with the Echinosphærite Limestone of Scandinavia and the Baltic provinces, and the occurrence of species hitherto known only from the Sedaw Limestone and the similar mode of preservation probably indicate that this bed is to be correlated with it. While the whole facies of the Ordovician faunas is European and especially allied to that of Scandinavia and the Baltic provinces, there is apparently a close connection in the development of the beds and the characters of the faunas with those of the Northern Shan States, and not with those of Eastern Yünnan," described recently by Deprat and Mansuy.[1]

The beds containing graptolites, which have a Birkhill facies, are of Silurian age.

[1] Etude Géologique du Yünnan Oriental. *Mémoires. Service Géol. Indo Chine.* Vol. I, Part I, pp. 62-64.

FURTHER NOTES ON THE SPECIES "CAMAROCRINUS ASIATICUS" FROM BURMA, BY F. R. COWPER REED, M.A., F.G.S. (With Plate 29.)

SINCE the description of the species *Camarocrinus asiaticus* from the Nyaungbaw Beds of the Northern Shan States was published by the author in 1906,[1] several palæontologists have dealt with the characters and affinities of this remarkable genus. The general opinion appears to be that it is of the nature of a float or the specialised root of a crinoid, but the question can hardly be regarded as finally settled. Bather[2] has discussed the relations of the representative of this genus discovered by Clement Reid in 1906 in a lenticle of limestone at Catasuent Cove, Porthluney, Cornwall. Sardeson[3] has tried to trace its evolution from crinoidal root-structures, and Kirk[4] has more recently taken up the question in connection with eleutherozoic Pelmatozoa. The last mentioned writer has expressed the opinion that "it seems as firmly established as such a thing may well be that the bodies known as *Camarocrinus* or *Lobolithus* are the distal expansions of *Scyphocrinus*." A supposed example of *Camarocrinus* from stage Dd 2 in Bohemia has been described by Fritsch[5] as *C. quartzitarum*, but Kirk (op. cit.) regards this fossil as an inorganic concretion.

The discovery of another fine specimen of *C. asiaticus* at the original locality, Yemeye, in the Nyaungbaw Beds, showing certain features not preserved in the previously known examples, allows us to amplify the specific description by the addition of several interesting and important details.

This new specimen is somewhat weathered, but fairly perfect, and it has a depressed spheroidal shape, rather elliptical in outline, the flattening being probably mainly due to compression in the rock. One surface (the so-called "upper" surface) is quadrilobate, but the opposite "basal," or stem-bearing side, shows a pentameral

[1] Reed, Lower Palæozoic Fossils of the Northern Shan States, *Pal. Ind.* N. S., Vol. II, Mem. 3 (1906), p. 87, pl. VIII, figs. 16, 16a—c.
[2] Bather, *Trans. Roy. Geol. Soc. Cornwall*, Vol. XIII, 1907, pt. III, pp. 191—197.
[3] Sardeson, *Journ. Geol., Chicago*, Vol. XVI, 1908, p. 250.
[4] Kirk, *Proc. U. S. Nat. Mus.*, Vol. 41 (1911), pp. 54—56.
[5] Fritsch, *Miscell. Palæz.* I, 1907, p. 5.

arrangement of parts with bilateral symmetry. On this side there is a well preserved basal joint for the attachment of a stem, and from it proceed five radiating divergent segmented cylindrical roots attached at their distal extremities only to the surface of the body. The basal joint of the stem does not seem to rest on the surface of the body but to be raised above it, the roots diverging downwards to connect the stem with the body. The shape of the basal joint is that of a regular elongated pentagon, longer than wide, and it is wedged into the roots, just as Schuchert[1] illustrated and described in the American species *C. Ulrichi*. The small pentagonal axial canal observed in the previously described example of *C. asiaticus* is not visible in the new specimen owing to weathering and attrition of the joint.

The five roots proceeding outwards nearly horizontally from the basal joint are jointed like the stem of a crinoid and have a regular radial arrangement, there being a single unpaired " anterior " root with two pairs of lateral roots. The unpaired root may be considered as anterior in position on the analogy of the ambulacral passages beneath the tegmen of the camerate crinoids.

The angle of divergence between the paired roots differs, that between the two posterior laterals being rather more than 90°, while that between the anterior and posterior lateral on each side is only about 45°. The angle between the anterior lateral and the unpaired anterior root is about 75°. The posterior lateral roots may be regarded as embracing what corresponds to the anal interradius on the analogy of the calyx.

All the roots bifurcate regularly once at an equal distance from the base of the stem, and the secondary branches thus formed diverge nearly at right angles.

The roots are uniserial, the primary portion being composed of 3—4 shallow cylindrical joints of equal size with the diameter about twice the thickness of a joint; and the bifurcation takes place after the fourth joint. The secondary branches are smaller and shorter, being only about half or two-thirds the diameter of the primary root and consist of 2—3 segments. The extremities of these secondary branches broaden out as the result of an incipient tertiary bifurcation, fusing immediately with the surface of the body, and these expanded terminations of the roots

[1] Schuchert, *Smithsonian Miscell. Coll.*, Vol. 47, No. 1482 (1904), pp. 253—272, text figure 44.

are in contact laterally, forming a ring enclosing a sub-circular area and apparently elevated into a "collar," as Schuchert described and figured in *C. Ulrichi*. But this part of our specimen is worn and weathered, so that only the base of the collar and its origin from the union of the distal expansions of the branches of the roots are traceable. Vestiges of the internal canals traversing the roots may be observed here and there.

An interesting feature in this "basal" surface of the body is that it seems to be quinquelobate, while the "upper" surface is quadrilobate. The anterior unpaired root is directed along the middle line of one lobe of the surface and this lobe lies over the constriction or groove separating two of the lobes of the "upper" surface. The primary literal roots are similarly directed along the middle lines of the four other lobes on the stem-bearing surface. Pentameral symmetry of this basal surface was mentioned by Schuchert, but it is strange that the disposition of the four lobes on the "upper" surface should be independent and wanting in correspondence. In my previous description of *C. asiaticus* the somewhat crushed and imperfect basal surface of the specimen then known was believed to be quadripartite, but probably it is typically in possession of pentameral symmetry. The imperfect state of preservation was likewise the cause of the statement that the stalk was situated on one of the lobes of the surface instead of being median in position. Schuchert (op. cit.) says that in *C. Ulrichi* the stalk is generally placed a little excentrically. It may here be remarked that the root which Schuchert terms in the species "the high, most prominent root member" corresponds apparently with the anterior unpaired root of *C. asiaticus*. With regard to the minute structure of the plates and test of this species there is nothing to be added to my previous description, except that on the stem-bearing surface the test is much thicker and thus agrees with Schuchert's observation (op. cit., p. 267). The edges of the walls of some of the internal cameræ can be distinguished where the test has been worn away, and their origin in the terminal bifurcation of the roots can be plainly seen, as Schuchert noticed in the case of other species. But for the determination of the internal arrangement of the cameræ, a series of transverse sections through the body would be necessary.

The dimensions of the above described new specimen of *C. asiaticus* are as follows :—Length 150 mm.; width 125 mm.; thickness

65—70 mm.; diameter of area surrounded by collar 40 mm.; length of basal joint of stem 12 mm.; width of ditto 9 mm.

Finally, we may emphasise the close resemblance of this species to *C. Ulrichi*, and the marked basal development of the pentameral symmetry.

EXPLANATION OF PLATE 29.

Camarocrinus asiaticus, Reed.

FIG. 1.—Lower surface (nat. size), showing base of stem collar and pentamerous symmetry of roots and lobation.

FIG. 2.—Upper surface of same specimen ($\times \frac{4}{5}$), showing the four lobes, the position of the roots and collar on lower surface being indicated by broken lines.